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Pellagra. An England case diagnosed by Dr. Sambon.

TROPICAL DISEASES

A MANUAL OF THE DISEASES OF WARM CLIMATES

BY

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WITH 12 COLOUR AND 4 BLACK-AND-WHITE PLATES AND 239 FIGURES IN THE TEXT

Fifth Edition, Revised throughout and Enlarged

NEW YORK

WILLIAM WOOD AND COMPANY

MDCCCCXIV

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PREFACE TO THE FIFTH EDITION

SINCE the publication of the Fourth Edition of this Manual in 1907 tropical medicine has continued to advance in a remarkable manner. Some of the advances have been briefly described in the several reprints which the publishers have been obliged to issue from time to time, but up to the present there has been, since 1907, no general revision of the text. Such a revision has become absolutely necessary if the Manual is to continue to be of service to the student of tropical medicine.

To show how necessary such a revision has become, I need only mention some of the more recent advances in tropical pathology. For example, the discovery that kala-azar, especially the infantile form, is a not infrequent disease in the countries surrounding the Mediterranean Sea, and also elsewhere in tropical and sub-tropical countries, that it is intimately associated in many of these countries with the dog, and that peculiar forms of dermal leishmaniasis are to be found in South America; that the transmission of *Trypanosoma gambiense* by *Glossina palpalis* is not, as was supposed, a simple mechanical process, but, as Kleine has shown, involves a necessary biological evolution in the insect; that a peculiarly virulent form of the trypanosome occurs in Rhodesia, which is transmitted by *Glossina morsitans;* that there exists in South America a form of trypanosomiasis which is transmitted by *Lamus megistus;* that a specific form of three-days' fever is caused by an unknown germ

introduced into the human subject by the bite of a phlebotomus; that, as has been pointed out by Castellani, yaws is produced by a spirochæte closely resembling that of syphilis; that beriberi, at all events in the Malay States, is the result of a diet of over-milled rice, as indicated by Braddon and proved by Fraser and Stanton; that there is a non-periodic variety of *Filaria bancrofti* specially common in the Pacific Islands; that *Schistosomum japonicum* is by no means an uncommon parasite in large districts of China and Japan, that it gives rise to a deadly disease, and that it is acquired by contact with the water of certain districts. These and many minor discoveries which might be mentioned, all made within the last few years, testify to the activity in pathological research into tropical disease, and the necessity for a thorough revision of this Manual.

I might point out that, whilst tropical pathology has been so actively and successfully studied, the prevention and treatment of tropical disease have not been neglected, and in the case of more than one disease investigation in these directions has had most gratifying results. To mention but a few, I would point to the prevention and treatment of beriberi on the lines indicated by the discoveries of Braddon, Stanton, and Fraser; the treatment of yaws and relapsing fever by salvarsan; the treatment of trypanosomiasis by antimony; and, perhaps the most important of all, the substitution of emetine for crude ipecacuanha in the diagnosis and treatment of amœbic dysentery and amœbic abscess of the liver, an advance which we owe to Leonard Rogers.

I have to acknowledge my great indebtedness to Dr. Philip Hahr for the invaluable assistance he has rendered me in preparing this new edition of my Manual. I must especially thank him for the care

he has taken in rewriting the Appendix on protozoa so as to bring it into conformity with the generally accepted teaching of the subject in this country; and I have also to thank him for revising the nomenclature of the many parasites which form so important a feature of tropical pathology.

P. M.

PREFACE TO THE FIRST EDITION

A MANUAL on the diseases of warm climates, of handy size, and yet giving adequate information, has long been a want; for the exigencies of travel and of tropical life are, as a rule, incompatible with big volumes and large libraries. This is the reason for the present work.

While it is hoped that the book may prove of practical service, it makes no pretension to being anything more than an introduction to the important department of medicine of which it treats; in no sense is it put forward as a complete treatise, or as being in this respect comparable to the more elaborate works by Davidson, Scheube, Rho, Laveran, Corre, Roux, and other systematic writers in the same field.

The author avails himself of this opportunity to acknowledge the valuable assistance he has received, in revising the text, from Dr. L. Westenra Sambon and Mr. David Rees, M.R.C.P., L.R.C.P., Superintendent, London School of Tropical Medicine. He would also acknowledge his great obligation to Mr. Richard Muir, Pathological Laboratory, Edinburgh University, for his care and skill in preparing the illustrations.

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INTRODUCTION

THE ETIOLOGY OF TROPICAL DISEASES

THE title which I have elected to give to this work, TROPICAL DISEASES, is more convenient than accurate. If by "tropical diseases" be meant diseases peculiar to the tropics, then half a dozen pages might have sufficed for their description; for, at most, only two or three comparatively unimportant diseases strictly deserve that title. If, on the other hand, the expression "tropical diseases" be held to include all diseases occurring in the tropics, then the work would require to cover almost the entire range of medicine; for the diseases of temperate climates are also, and in almost every instance, to be found in tropical climates.

I employ the term "tropical" in a meteorological, rather than in a geographical, sense, meaning by it sustained high atmospheric temperature; and by the term "tropical diseases" I wish to indicate diseases occurring only, or which from one circumstance or another are specially prevalent, in warm climates.

It must not be inferred from this, however, that high atmospheric temperature is the sole and direct cause of the bulk of tropical diseases. The physiological machinery of the human body is so adjusted that great variations of atmospheric temperature can be supported by man with impunity. Indeed, although temperature acts as an important pathogenic factor, it is very rarely that it does so directly. Extreme cold may cause frost-bite; exposure to the sun, sun erythema, sun headache, and symptomatic fever; a hot atmosphere, heat exhaustion; prolonged residence in hot moist climates, vague, ill-defined conditions of debility; profuse sweating from heat of climate,

prickly heat. But none of these states can with justice be regarded as disease.

This being so, it is natural to ask: In what way do tropical influences affect disease, as they undoubtedly do; and why should it be that some diseases are peculiar to tropical climates, or are specially prevalent in such climates?

Speaking generally, the natives of tropical countries are not injuriously affected by the meteorological conditions of the climates they live in, any more than are the inhabitants of more temperate climates; their physiological activities are attuned by heredity and habit to the conditions they were born into. The European, it may be, on his first entering the tropics, and until his machinery has adjusted itself to the altered meteorological circumstances, is liable to slight physiological irregularities, and this more especially if he persist in the dietetic habits appropriate to his native land. A predisposition to certain diseases, and a tendency to degenerative changes, may be brought about in this way; but acute disease, with active tissue change, is not so caused. In the tropics, as in temperate climates, in the European and in the native alike, nearly all disease is of specific origin. It is in their specific causes that the difference between the diseases of temperate climates and those of tropical climates principally lies.

Modern science has clearly shown that nearly all diseases, directly or indirectly, are caused by germs. It must be confessed that although in many instances these germs have been discovered, in other instances they are yet to find; nevertheless, their existence in the latter may be confidently postulated.

Germs are living organisms, and, like all living things, demand certain physical conditions for their well-being. One of these conditions is a certain temperature; another is certain media; and a third is certain opportunities.

In the majority of instances disease germs are true parasites, and therefore, to keep in existence as species, require to pass from host to host. If, during this passage from host to host, the temperature of the

transmitting medium—be it air, water, or food—be too high or too low for the special requirements of the germ in question, that germ dies and ceases to be infective. In this way may be explained the absence from the tropics of a class of directly infectious diseases represented by scarlet fever, and the possible absence from temperate climates of a similar class of diseases. In the one case, during the short passage from one human being to another, tropical temperature is fatal to the air-borne germ; in the other it may be that the lower temperature of higher latitudes has the same effect.

In another type of disease, of which tropical scaly ringworm (tinea imbricata) is an excellent example, the germ vegetates on the surface of the body, and is thus exposed to the vicissitudes of climate. One of the requirements of the germ referred to is a high atmospheric temperature and a certain degree of moisture. Given these it flourishes; remove these and it dies out, just as a palm tree or a bird of paradise would die on being transferred to a cold climate.

Many diseases require for their transmission from one individual to another the services of a third and wholly different animal. The propagation and continued existence of a disease of this description will depend, therefore, on the presence of the third animal. If the latter be a tropical species, the disease for the transmission of which it is indispensable must necessarily be confined to the tropics. Thus the geographical range of malaria and of filariasis is determined by that of certain species of mosquito which ingest and act as alternative hosts to the respective germs, and, so to speak, prepare them for entrance into their human host. The distribution of a large number of animal parasitic diseases depends in this way on the distribution of these alternative hosts. When this animal happens to be a tropical species, the disease it subtends, so to speak, is, in natural conditions, necessarily tropical also.

Certain diseases are common to man and the lower animals. If these latter happen to be tropical species

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[illegible] and ankylostomiasis

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[illegible] external media, and whose
[illegible] human body as a necessary
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[illegible] and its toxin, alcohol, and
[illegible] alcoholism, are the most familiar
[illegible] Such, too, are ergotism, atriplicism,
[illegible] These germs require certain
[illegible] certain media; consequently the
[illegible] have a corresponding geogra
[illegible] one of these conditions be a high
[illegible] disease is mainly a tropical one.
[illegible] can conceive, and believe, that there is
[illegible] less directly-acting set of conditions influ-
[illegible] distribution of disease—conditions which
[illegible] been ignored by epidemiologists, but
[illegible] seems to me, must have an important bear-
[illegible] subject. Disease germs, their transmitting
[illegible] or their intermediate hosts, being living
[illegible] are, during their extracorporeal phases,
[illegible] competing organisms, and therefore liable
[illegible] preyed upon or otherwise crushed out by other
[illegible] in the struggle for existence. The malaria
[illegible] is absent in many places in which, appar-
[illegible] all the conditions favourable to its existence
[illegible] to be found in perfection. Why is it not found
there, seeing that it must certainly have been fre-
quently introduced? I would suggest that in some
instances this and other disease germs, or the organ-

isms subtending them, are kept under by natural enemies which prey on them, just as fishes prey on and keep down water-haunting insects, or as mice do humble-bees. The geographical range of such disease germs, therefore, will depend, not only on the presence of favourable conditions, but, also, on the absence of unfavourable ones. Herein lies a vast field for study, and one which, as yet, has not been touched by epidemiologists.

In these and similar ways the peculiar distribution of tropical diseases is regulated. The more we learn about these diseases the less important in its bearing on their geographical distribution, and as a direct pathogenic agency, becomes the rôle of temperature *per se*, and the more important the influence of the tropical fauna.

Whatever may have been the original source of the pathogenic parasites of man, it is certain that many of those which have a wide distribution at the present day were much more restricted originally The extension of many of them has occurred within historical, and of some even in recent, times. Thus, in the last century, cholera spread over a great part of the world from its reputed home in India. Small-pox and other Old-World diseases have crossed the Atlantic; and some originally American diseases, such as syphilis and the chigger, have appeared in the Old World; measles, whooping-cough, tuberculosis, and leprosy have been introduced into the Pacific Islands. The process of diffusion is still proceeding, assisted, doubtless, by the vastly increased rapidity and frequency of modern travel, and by the breaking down in recent times of social, political, and physical barriers that formerly isolated many communities, some of which had been from time immemorial the sole repositories of particular disease germs. Thus the sleeping sickness of West Africa is passing to East Africa, and thus, most probably, the yellow fever of America will pass to Asia.

There is one factor which undoubtedly has contributed powerfully to delay the diffusion of certa

tropical diseases—the circumstance that most of them depend on protozoal or some other kind of animal germ requiring for its transmission an animal intermediary. Diseases which depend on bacterial germs, if their special bacterium be introduced, social and sanitary conditions being favourable, will spread in any country or climate, and thus it is that all bacterial diseases, with hardly an exception, are found, or are capable of existing, everywhere; in the passage from host to host their germs are not killed by ordinary atmospheric conditions, and they require no second intermediary. Diseases depending on protozoa or other animal germs, in many though not in all instances, will not establish themselves thus universally, because their germs in the passage from host to host demand, through their intermediaries or otherwise, very special and climatically restricted conditions. Tropical diseases belong for the most part to this category, and therefore their successful introduction and spread to new ground are attended with more difficulty than bacterial diseases, demanding, as the former generally do, the double condition of the successful introduction not only of the germ itself but also of the intermediary.

Although this double necessity has undoubtedly operated powerfully against the spread of certain tropical diseases, there is reason to believe that in time this difficulty will disappear; for, so far as we know, there is no reason why, if introduced into new places, these animal intermediaries should not obtain a permanent footing and spread.

There are many instances of exotic insects, for example, which have established themselves after either accidental or intentional introduction into new countries. There is no reason, therefore, for thinking that disease-germ insect intermediaries could not be similarly established in countries in which they are unknown at present. Thus, if the tse-tse flies were successfully introduced into India, sleeping sickness might appear there in due course; or, if appropriate anopheles were introduced into

many at present malaria-free and salubrious Pacific Islands, malaria would become established there. And thus, though certain tropical diseases have at present a limited range, there is great probability, unless measures are speedily set on foot to prevent such a calamity, that the swift and increasing intercourse of modern times, by facilitating the intentional or accidental introduction of their subserving intermediaries, will ere long enable them to extend their present geographical range.

It is evident from what has been advanced that the student of medicine must be a naturalist before he can hope to become a scientific epidemiologist, or pathologist, or a capable practitioner. The necessity for this in all departments of medicine is yearly becoming more apparent, but especially so in that section of medicine which relates to tropical disease. This is further accentuated if we reflect that, although we do know something about a few of the tropical diseases and their germs, there must be many more tropical diseases and tropical disease germs about which we know absolutely nothing. Who can doubt that just as the fauna and flora of the tropical world are infinitely richer in species than those of colder climates, so there is a corresponding distribution in the wealth and poverty of pathogenic organisms; and that many, if not most, of the tropical diseases have yet to be differentiated? The discoveries of the last few years show this. Opportunities and appliances for original pathological study are, from circumstances, too often wanting to the tropical practitioner; but in this matter of the etiology of disease he certainly enjoys opportunities for original research and discovery far superior in novelty and interest to those at the command of his fellow-inquirer in the well-worked field of European and American research.

In the following pages I have included certain cosmopolitan diseases, such as leprosy, plague, and beriberi, diseases which, properly speaking, do not depend in any very special way, or necessarily, on climatic conditions. They have been practically ousted fr

Europe and the temperate parts of America by
spread of civilisation and the improved hygiene
has followed in its train. They are now virtu
confined to tropical and sub-tropical countries, w
they still survive under those backward social
sanitary conditions which are necessary for t
successful propagation, and which are more or les
indirect outcome of tropical climate.

TROPICAL DISEASES

Section I.—FEVERS

CHAPTER I

MALARIA

Definition.—Morbid conditions produced by certain protozoal parasites belonging to the class Sporozoa, whose definitive host is the mosquito, and whose intermediate host is man and, possibly, other vertebrates. In man these parasites inhabit the red blood-corpuscles, giving rise to fever—usually of a periodic character—anæmia, enlargement of the spleen, and the deposit of a black pigment in the viscera and elsewhere. Some of their phases are amenable to quinine.

HISTORY

The history of malaria goes back to times of remotest antiquity. Already in the fifth century B.C. Hippocrates recognized the existence of periodic fevers, and divided them into quotidian, tertian, subtertian, and quartan. Galen, Celsus, and other Roman writers also gave accurate descriptions of these fevers.

From the classic period until about the middle of the seventeenth century there was no material advance in knowledge regarding malaria, but the introduction of cinchona in 1640 enabled Morton and Tort to separate the malarial fevers from other febrile diseases, and to show that some continued and remitting fevers belong to the same group as the intermittents.

The next important step was the discovery of the characteristic pigmentation of the viscera in malaria.

In 1847, Meckel described certain pigment-bearing cells which he had found in the spleen and in the blood at the post-mortem of a patient who had died of malaria. Virchow was able to confirm this observation, and Planer in 1854 noted these pigmented cells in fresh blood from the finger of malarial patients. These cells were, of course, the malarial parasites, although their true nature was not apprehended at the time.

The parasitic nature of malaria, which had been suspected since the days of Varro and Columella, was definitely established by Laveran, who in 1880, having noticed the eruption of long motile filaments from the pigmented cells described by Meckel and Planer, was the first to recognize their parasitic character.

Laveran's observations were soon extended by Marchiafava, Celli, Golgi, Bignami, Bastianelli, and other investigators, but especially by Golgi, who demonstrated the definite correlation between the development of the parasites and the periodicity of the fever paroxysms, and showed that the different types of malarial fever correspond to different species of parasites.

The association of the malarial parasites with certain mosquitoes, suggested by epidemiological facts, and by certain phases in the life history of the parasite indicating the necessity of alternation of generations, together with a change of host as in other haemo-parasites, was definitely established by Ross's investigations and the experiments carried out by the Italians and ourselves.

Finally, the application of these recent discoveries to the diagnosis and prevention of malaria has led to practical measures which have already been fruitful in good results and promise yet more.

Proofs that the Malaria Parasites are the Cause of Malarial Disease

It is now placed beyond doubt that the presence and proliferation in the blood of these parasites, discovered by Laveran in 1880, are the cause of what was formerly and is still known as "malarial

disease." The following is a summary statement of the principal reasons for this belief:—

1. The occurrence of the parasites in the blood is practically always, sooner or later, associated with the clinical phenomena of malarial infection.

2. Malarial fever throughout, or at one time or another during its course, is invariably associated with the presence of one or other of these parasites in the blood.

3. The phases of a malarial fever bear a definite relation to the phases of the life-cycle of the particular parasites present in the blood.

4. That absolutely characteristic feature of malarial disease, malarial pigmentation of viscera, is fully accounted for by the pigment-forming property of the parasites.

5. Intravenous or subcutaneous injection of blood from a case of malarial infection—that is, of blood containing the parasite—is generally, after an incubation period of eight to twelve days, followed by an attack of malarial fever, and by the appearance in the blood of the person injected of the same species of malaria parasite.

6. The administration of quinine, which brings about the cessation of the clinical symptoms of acute malarial infection, rapidly causes most phases of the parasite to disappear from the blood.

7. If, after they have imbibed malarial blood, certain species of mosquitoes be dissected at serial intervals, the evolution of the malaria parasite can be followed in their tissues until, finally, the germs of the parasite can be tracked into the cells and secretion of the salivary glands of the insect.

8. If after a week, or thereabouts, a similarly-fed mosquito bite a hitherto uninfected man, in many instances, after a few days, that man will exhibit the clinical phenomena of malarial infection and the characteristic parasite in his blood.

9. A non-immune, if effectually protected against mosquito bite, will not contract malarial disease, however long he may live in highly malarious localities.

The proof of the causal relationship of the para

site to the disease may therefore be said to be complete.

Morphology and Histology

There are several species of malaria parasites. The distinctive characteristics of each of these will be detailed in Chap. III. The following brief description is confined to what may be regarded as the generic features common to all.

The three phases.—The malaria parasite, like all true parasites, must be adapted not only for a life inside its hosts, but also, in order that its continuance as a species may be assured, for a passage from one host to another. Consequently, as regards man, it exhibits two distinct phases—an intracor-

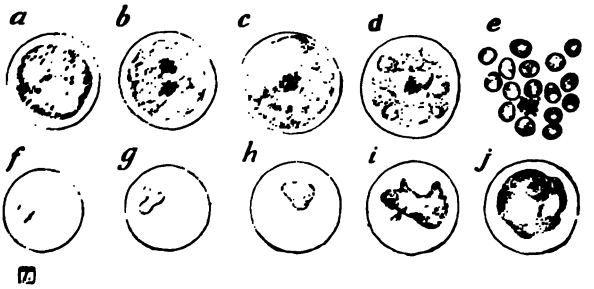


Fig. 1.—Evolution of the tertian parasite, unstained (see text).

poreal and an extracorporeal. Clinical observation and analogy make it certain that there is yet another phase, also intracorporeal—the latent phase, whose characters as yet can only be conjectured.

Intracorporeal or Human Cycle

Each species of malaria parasite has its special and more or less definite intracorporeal life-span or cycle of twenty-four hours, of forty-eight hours, or of seventy-two hours.

On examining microscopically malarial blood towards the end of one of these cycles, an hour or two before the occurrence of a paroxysm of the characteristic periodic fever it induces, the parasite may be

recognized as a pale, somewhat ill-defined disc of protoplasm occupying a larger or smaller area within a proportion of the red blood-corpuscles (Fig. 1, *a*). Scattered through this pale body are a number of intensely black or reddish-black particles—an excrementitious material called hæmozoin.*

Changes in the parasite.—By making fresh blood preparations and repeating his examinations at short serial intervals, the observer is enabled to infer that the following changes systematically occur in this disc of pigmented protoplasm. After a time, as the parasite matures, the scattered hæmozoin particles collect into little groups, sometimes into radiating lines. These hæmozoin groups subsequently concentrate into one or two larger and more or less central blocks, around which the pale protoplasm of the parasite arranges itself in minute segments which finally acquire a globular form and appear as well-defined spherules (Fig. 1, *b*, *c*, *d*). The including blood corpuscle then breaks down, and the spherules, none of which contains hæmozoin, fall apart, and, along with the clump or clumps of hæmozoin, become free in the liquor sanguinis (Fig. 1, *e*). The phagocytes now quickly absorb the hæmozoin and many of the spherules. A proportion of the latter, escaping the phagocytes, attach themselves to other blood corpuscles which they contrive to enter (Fig. 1, *f*). In the interior of these newly infected corpuscles the young parasites exhibit active amœboid movement, shooting out and retracting long pseudopodia, and growing at the expense of the hæmoglobin (Fig. 1, *g*). This substance they assimilate, converting it into the pale protoplasmic material constituting the mass of the parasite and into the hæmozoin particles (Fig. 1, *h*, *i*). As the parasite becomes larger its amœboid movements gradually slow down until all motion finally ceases; just before the formation of spherules and completion of the cycle (Fig. 1, *j*), beyond slight translation

* The term "hæmozoin" suggested by Sambon is here employed instead of "melanin" hitherto in use, which has a [illegible] and different physiological meaning. The term "black p[illegible] is vague and incorrect.

movement of the hæmozoin particles, the parasite is passive.

Structure of the parasite.—By appropriate staining of the free spherule (Fig. 2, *b*, *c*, *d*) it is found to consist of a minute, deeply tinted chromatin mass, the nucleolus, surrounded by an unstained area regarded by many as a vesicular nucleus, and this again by a somewhat lightly tinted covering of protoplasm. After the spherule has entered a blood corpuscle (Fig. 2, *e*), staining shows that the vesicular nucleus has become larger and more distinct, that the protoplasm has increased in bulk, and that the deeply stained nucleolus, which is sometimes double, has

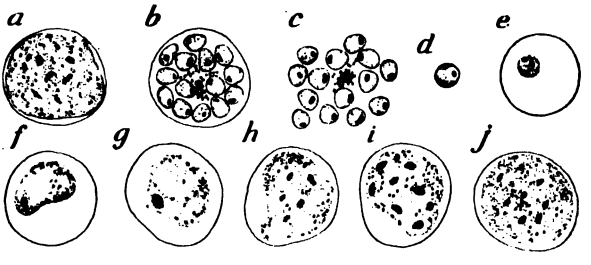


Fig. 2.—Evolution of the tertian parasite, stained (*see* text).

come to lie eccentrically in the nucleus, and both of them eccentrically in the protoplasm. On account of the relatively large size of the unstained nucleus, the eccentric position of the deeply stained nucleolus, and the narrow rim of stained protoplasm, the younger parasites look like so many minute blue signet-rings stuck on to the blood corpuscles. As the parasite grows and approaches maturity the nucleolus enlarges, becomes less defined, and then disperses; the vesicular nucleus also becomes enlarged and less distinct (Fig. 2, *f*, *g*, *h*, *i*). Finally, just before sporulation, both nucleus and nucleolus cease to be distinguishable (Fig. 2, *j*, *a*). At this stage these elements become fragmented and diffused throughout the protoplasm. Later the nuclear elements reappear as numerous minute, scattered nucleoli; and it is

around these that the protoplasm of the segmenting parasite arranges itself to form the spherules (Fig. 2, *b*, *c*). The vesicular character of the nucleus does not usually appear in the spherules until after these have become free in the liquor sanguinis (Fig. 2, *d*).

The hæmozoin particles, so characteristic of the malaria germ, occur as black or very dark-red dust-like specks, coarse grains, or short rods, either isolated or aggregated into larger or smaller, more or less dense clumps. Until the concentration of hæmozoin which precedes the formation of spherules takes place the particles are scattered, being located principally in the outer zone, or ectosarc, of the parasite. Apparently so long as the nucleus remains entire the hæmozoin is peripheral; when segmentation occurs in the nucleus the hæmozoin becomes central.

Such is a brief account of the cycle and structure of one phase of the parasite. From it we may understand how the parasite maintains itself and multiplies inside the human body. It does not explain, however, the two other important biological features which analogy and observation clearly indicate—namely, its latency in, and its life outside, the human body.

Extracorporeal or Mosquito Cycle

As it is unreasonable to suppose that an organism which propagates so actively in the human body has no opportunity, either by passing from one host to another or in other ways, of continuing its species, we are forced to conclude that some provision must exist in the economy of the parasite that enables it to leave and enter successive hosts. The problems suggested by this consideration are—first, how does the malaria parasite leave the human body; second, what is its life when temporarily outside the human body; and, third, how does the parasite re-enter the human body?

The flagellated body.—When fresh malarial blood is examined some time after it has been mounted as a wet preparation, it is no unusual thing to see

what is known as the "flagellated body"* (Fig. 3). Analogous bodies are found in all forms of malaria, both in those special to man and in the corresponding infections of other vertebrata. It is a strange-looking, octopus-like creature with long, actively-moving arms. Though composed of the same materials—namely, colourless protoplasm and dark hæmozoin granules—it differs in many respects from the ordinary forms of the parasite, more especially in the fact that it is not intracorpuscular, but free

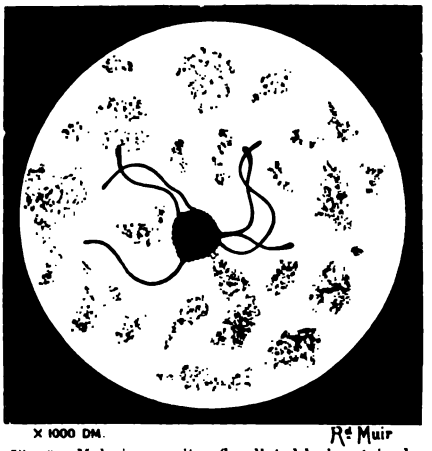


Fig. 3.—Malaria parasite: flagellated body, stained.

in the liquor sanguinis. The long, whip-like arms, numbering from one to six, or even more, are usually designated *flagella* or, more correctly, microgametes. These are exceedingly delicate and pliant filaments, difficult to see not only on account of their delicacy but also on account of the rapidity of their movements. Sometimes bulbous at the free extremity,

* The expressions "flagellated body" and "flagellum," applied to this phase of the malaria parasite, though graphic enough, are somewhat misleading. The flagella of the malaria parasite are in no sense analogous to the flagella of the flagellata; they really function as spermatozoa. The proper zoological terms for this and the other phases of the malaria parasites are given at p. 28.

sometimes presenting one or more swellings in their continuity, the microgametes are three or four times as long as a blood corpuscle is broad. At first they are attached to the periphery of the pigmented central, more or less spherical body, which is about half the diameter of a red blood-corpuscle. Their movements are so vigorous that they double up or otherwise distort temporarily those corpuscles with which they chance to come in contact. Occasionally it may be observed that one or more of the microgametes

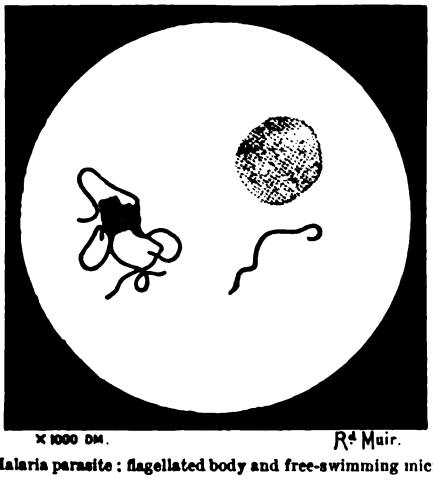


Fig. 4.—Malaria parasite: flagellated body and free-swimming microgamete.

break away from the central sphere and swim free in the blood (Fig. 4), remaining active for a considerable time—several hours, perhaps—before finally vanishing. When swimming free in the plasma, and also while still attached to the sphere, the microgamete indulges in three kinds of movement: (*a*) an undulatory movement, evidently subserving locomotion; (*b*) a vibratory movement, apparently provoked by contact with a resisting body, as a blood corpuscle, for in such circumstances the little filament is sometimes seen to straighten itself out and quiver like a slender rod when it is struck on the ground; (*c*) a

coiling-up movement, usually seen just before the microgamete finally ceases to move.

It is of importance to bear in mind that these flagellated bodies are never seen in newly drawn blood, and that they come into view only after the slide has been mounted for some time—ten to thirty minutes, or even longer, according to circumstances.

Source of the flagellated body.—Careful observation shows that the flagellated bodies are developed from a particular phase of the intracorpuscular parasite, a phase which differs in form according to species—namely, in certain types from what is known as the "crescent body"; in other types from certain large intracorpuscular parasites closely resembling the mature parasite (Fig 1, *j*) just prior to concentration of hæmozoin and segmentation.

The crescent body.—These bodies, and consequently the flagellated body, are not present in the blood at the commencement of a malarial infection, or necessarily, especially if it be long delayed, at the commencement of the recrudescence of a latent infection. They come into the blood only after a week or ten days of acute clinical symptoms. At first few in number, and perhaps difficult to find, they gradually become more numerous and persist for days after the disappearance of the other forms of the parasite and the decline of the acute symptoms, and then gradually disappear. Unlike the other forms of the parasite, they are not affected by quinine. They may vanish from the blood after a week, or persist in it for six weeks or longer. They may be very numerous, several in every field of the microscope, or so scanty that many preparations may have to be searched before one is found. Not infrequently they cannot be discovered at all; especially is this the case in malignant (subtertian) infections in the tropics, although, strange to say, when the same patients suffer a relapse in Europe it is generally easy enough to find the crescent body in the blood.

The shape, size, and structure of the crescent body can best be comprehended from the illustration (Fig. 5). It exhibits no amœboid movements.

The principal features to be noted are its very definite crescentic shape; the probable existence of a delicate limiting membrane; the presence of needle-shaped hæmozoin particles, usually about the centre of the parasite, though sometimes nearer one end; and a bow-like and exceedingly delicate line that, springing from a point somewhat inside the rounded-off tips of the horns of the crescent, bridges its concavity. Manifestly this bow represents the outline of the remains of the blood corpuscle in

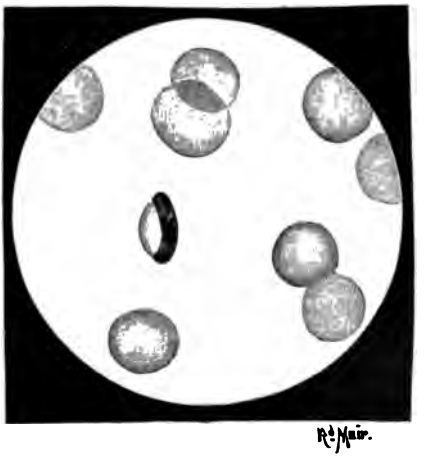


Fig. 5.—Malaria parasite: the crescent body; stained. (× 1000.)

which the parasite had developed. In many instances, especially in stained specimens, the continuation of the red blood-corpuscle can be distinctly traced around the convexity of the crescent. This circumstance, together with the fact that the material included by the bow, and also occasionally seen as a delicate, sometimes slightly jagged fringe around the convexity of the crescent, gives the staining reactions of hæmoglobin, proves that this form of the malaria parasite, like the ordinary amœboid bodies already described, is also intracorpuscular. Slight differences, particularly as regards

the sharpness or obtuseness of the horns, occur; but, on the whole, the crescents are very uniform in appearance. Very rarely twin or double crescents —that is, two crescents in one corpuscle—are encountered (Fig. 6).

Crescents differ in appearance according to their age; in some the hæmozoin granules are scattered throughout the parasite, in others they are concentrated, and in a third class the protoplasm shows vacuolation and other signs of degeneration. The first, it is believed, are young and immature, the second mature, and the third effete parasites. In the first, the hæmozoin rods sometimes exhibit slight translation as well as vibratory movements; in the two latter the hæmozoin is quiescent. The first, or younger, type of crescent stains uniformly; but in the second type the staining, in many instances, is markedly bipolar, a clear, unstained area occupying the middle of each horn, whilst a zone of stained protoplasm forms the periphery, and a bridge of stained material divides the two horns at the centre of the crescent. By dissolving the hæmozoin particles at the centre of the crescent with weak solution of ammonia, and subsequently staining, a nucleolus, sometimes double, can be demonstrated.

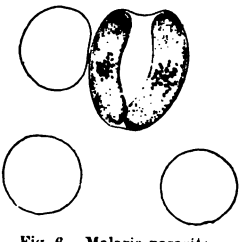


Fig 6.—Malaria parasite: twin crescents.

As will be shown in the sequel, these crescent bodies and the large intracorpuscular forms just alluded to are sexual in their functions. As regards the crescents, there are certain differences in the appearance of the protoplasm, in the arrangement of the pigment, and in the characters of the nucleus as revealed by staining, which are distinctive of the male and female crescents respectively. In one type of crescent the protoplasm is hyaline and the hæmozoin somewhat loosely arranged. In another type the protoplasm is faintly granular and the hæmozoin more concentrated, being arranged as a well-defined ring about the centre of the parasite

The former is male, the latter female. The protoplasm of the male parasite stains more deeply, and its nucleus is larger than that of the female parasite.

The more immature forms of the crescent are said to begin to be recognizable in the spleen and bone marrow about the fourth day after a subtertian malarial attack commences. At first, according to Bastianelli and Bignami, they are minute, highly refringent amœboid bodies. They are rarely encountered in peripheral blood; there the crescent body does not begin to show itself till it approaches maturity, about a week after the first crop of amœboid parasites associated with the fever paroxysm has appeared.

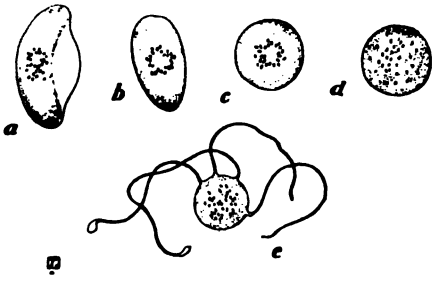


Fig. 7.—Evolution of the flagellated body from the crescent.

Formation of the flagellated body.—Ordinarily, if a number of crescent bodies are kept for a time under observation on the microscope slide a certain proportion of them will be seen slowly, or more rapidly, to undergo change of shape, gradually becoming converted into squat crescents, then into oval bodies, and then into spheres (Fig. 7, *a*, *b*, *c*), whilst the remains of the enclosing blood corpuscle fall to pieces or melt away. The remains of the blood corpuscle are often seen as a small, slightly hæmoglobin-tinted globule lying in contact with or near the parasite. The crescent-derived spheres are of two types in correspondence with the sex of the particular crescent from which they originate, some—the male—having hyaline, others—the female—having

granular protoplasm (Fig. 8). At first the hæmozoin particles in the crescent, in the oval body, and in the sphere are motionless and central; more rarely they are eccentric. By and by, in many of the spheres these particles tend to arrange themselves as a ring, lying in contact with the inner surface of what may be a very fine, invisible membrane, occupying

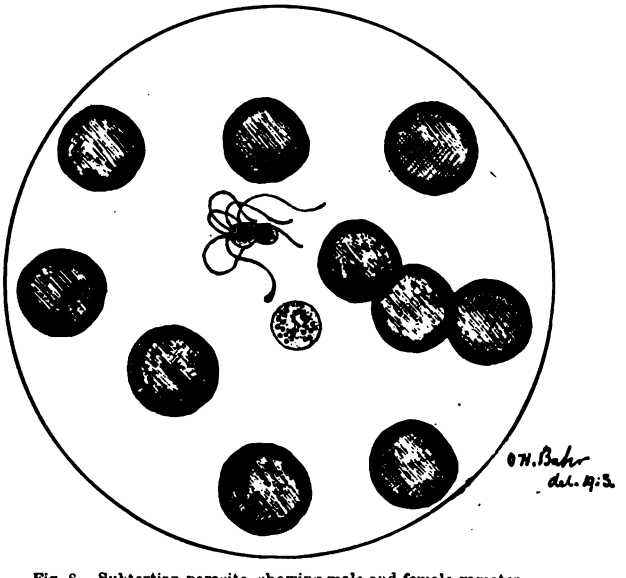


Fig. 8.—Subtertian parasite, showing male and female gametes approximated.

(*From a preparation by Dr. F. W. O'Connor.*)

the central third of the sphere, and forming, as it were, a small central sphere within the larger sphere. After a time in the hyaline spheres the hæmozoin particles begin—at first slowly and intermittently, afterwards more energetically—to dance about. As the movement of the pigment increases in rapidity and energy the entire sphere seems to partake in the agitation—to quiver, to change form, and to be jerked about as by some unseen force. The hæmozoin particles

may now become diffused through the general mass of the sphere (Fig. 7, *d*), or they may not. Whether this does or does not happen, the agitation of the sphere now becoming intense, one or more filaments are suddenly shot out from its periphery and at once begin to indulge in characteristic waving, lashing movements (Fig. 7, *e*).* The granular spheres do not project these filaments or microgametes.

In stained preparations it can be shown that the process of microgamete formation is preceded by fragmentation of the nucleus, the chromosomes proceeding to the periphery of the sphere and each becoming surrounded by a portion of protoplasm. The microgamete, therefore, is composed of these two elements drawn out into a thread—a chromatin filament enclosed in a covering of protoplasm. In the granular spheres there is no fragmentation of nucleus or filament formation, the minute nucleus remaining central surrounded by its circle of hæmozoin rods.

The extruded microgametes, if they do not break away as already described, may continue to move for an hour, or even longer—that is, if the flagellated body be not engulfed by a phagocyte, an occurrence very frequently witnessed. Finally, they slow down, cease to move, coil up perhaps, and then gradually fade from view. Should the microgametes succeed in breaking away, the remains of the flagellated body, consisting of hæmozoin particles included in a small amount of residual protoplasm, tend to assume a somewhat spherical, passive form, the hitherto violent changes of shape and the movement of the hæmozoin ceasing almost abruptly.

In other types of malarial infection certain bodies (Fig. 9, *a*, *d*), which, but for the brisk movements of their hæmozoin, look like ordinary full-grown intra-

* Careful focusing, especially of stained crescent-derived spheres, may sometimes show that for a short time before their eruption the microgametes exist preformed inside the limiting membrane of the sphere (Fig. 7, *e*). One can sometimes see a microgamete filament, in its efforts to erupt, carry this membrane in front of it, and, failing to break through, retract and perhaps renew the effort at another point. Doubtless, the agitated movements of the sphere are produced by the efforts made by the microgametes to break through this membrane.

corpuscular parasites prior to the formation of spores, may sometimes be seen to slip out from their enclosing corpuscles (Fig. 9, *b*, *e*). If these free parasites are watched, in some instances the hæmozoin they contain is seen to indulge in violent dancing movements, the body of the parasite being at the same time agitated and jerked about. Finally, "flagella" (microgametes) may be suddenly projected from the periphery (Fig. 9, *c*, *f*), very much in the same way as they are projected from the periphery of the crescent-derived sphere. Manifestly, these large

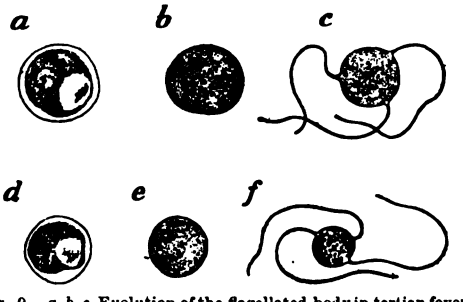


Fig. 9.—*a*, *b*, *c*, Evolution of the flagellated body in tertian fever; *d*, *e*, *f*, evolution of the flagellated body in quartan fever.

spherical parasites and the flagellated bodies arising from some of them correspond to the crescent-derived sphere and crescent-derived flagellated body.

Conditions favouring and retarding eruption of microgametes.—Ross has shown that, provided the blood containing the crescent body be prevented from coming in contact with the air, as can be secured by pricking the finger through vaseline, evolution does not proceed. He has further shown that if the droplet of blood is exposed to the air for a minute or two before being mounted on a slide, the eruption of microgametes is markedly encouraged. Similarly, Marshall has shown that it is also favoured by mixing the blood with a trace of water. I find that by combining these methods—namely, exposure to the air with slight aqueous admixture, as by breathing on the slip before applying the cover-glass—it is generally easy to procure quickly, from crescent-containing blood, specimens of the flagellated body. Probably, although I have not experimented with this object in suitable cases, the eruption of microgametes will be favoured in the non-crescent-forming parasites by similar means.

that is, until it is outside the body—I concluded that the function, then unknown, of the flagellum lay outside the human body, and that the flagellated body was the first phase of the extracorporeal life of the malaria parasite. As the parasite whilst in the circulation is always enclosed in a blood-corpuscle, and is therefore incapable of leaving the body by its own efforts, and as it is never, so far as known, extruded in the excreta, I concluded that it is removed from the circulation by some blood-sucking animal, most probably by some suctorial insect common in the haunts of malaria. This blood-sucker I believed to be the mosquito, an insect whose habits seemed adapted for such a purpose, and whose distribution conformed to the well-ascertained habits of malaria. Further, basing my argument on what I had shown to be the fact in the case of *Filaria bancrofti*, and on the peculiarities of the distribution of malaria, I reasoned that only particular species of mosquito were capable of subserving particular species of malaria parasite.

Ross's observations.—Ross, to whom I suggested the investigation of this hypothesis, first (1895) demonstrated the fact that when crescent-containing blood is ingested by the mosquito a large proportion of the crescents rapidly proceed to microgamete formation and to the emission of microgametes. In 1897 he showed that in a particular species of mosquito fed on malarial blood, living and growing malaria parasites containing hæmozoin are to be found embedded in the stomach wall of the insects. Early in 1898 (as announced by me at the meeting of the British Medical Association, in Edinburgh, in July, 1898) he showed that if a particular species of mosquito be fed on the blood of plasmodium-infected birds, the parasite, which both in habit and structure closely resembles the malaria parasite of man, enters the stomach wall of the insect, grows and sporulates there, and that the resulting sporozoites subsequently enter the salivary gland of the insect, and that the insect is then capable of infecting by its bite other birds. Ross further showed that only particular species of mosquito could subserve the avian plasmodium in this way, and that the particular mosquito

in question was not efficient as regards another blood parasite of birds—namely, hæmoproteus—or as regards the malaria parasites of man. Thus, by direct observation and by analogy Ross distinctly, and first, proved that the extracorporeal phase of the malaria parasite is passed in particular species of mosquitoes, and, by analogy, that the parasite is transferred from man to man by the mosquito.

MacCallum's discovery.—A gap in Ross's observations was filled in by MacCallum, who showed,

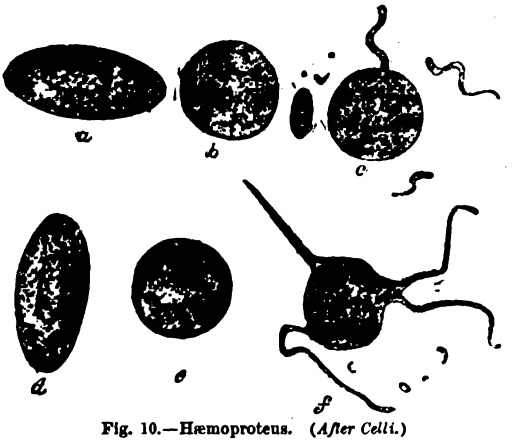


Fig. 10.—Hæmoproteus. (*After Celli.*)
a, b, c, Evolution of macrogamete; *c,* fertilization by microgamete; *d, e, f,* evolution of microgamete.

principally by observations on hæmoproteus, also a malaria-like parasite of birds, that the function of the filament after it breaks away from the parent sphere, or flagellated body, is to impregnate (Fig. 10, *c, f*) the granular crescent-derived spheres, which then become transformed into sharp-pointed travelling vermicules. Doubtless, although the process has not been directly observed, it is in virtue of the locomoting and penetrating properties of the travelling vermicule that the malaria parasite is enabled to lodge itself, where Ross first found it, in the stomach wall of the mosquito.

Confirmation and extension of Ross's work.—Ross's observations were quickly confirmed and elaborated by the Italians, by Daniels, and by Koch. Grassi has shown that several species belonging to the genus *Anopheles*, more particularly—at all events as regards Italy—*Anopheles maculipennis*, are the special mosquito-hosts of the malaria parasites of man. Step by step he traced the crescent-forming and the non-crescent-forming malaria parasites through their mosquito hosts, finding that in their evolution they closely resembled that which Ross had so successfully demonstrated for the avian plasmodium, and had so clearly foreshadowed and partly demonstrated for the malaria parasite of man. In conjunction with Bignami he repeated successfully in man Ross's experiment of conferring malarial disease by mosquito bite. Bastianelli, Celli, Dionisi, Buchanan, and others have also succeeded in confirming Ross's statements, and in adding to our knowledge of the extracorporeal cycle of the malaria parasite.

Finally, on behalf of the Colonial Office and the London School of Tropical Medicine, with the assistance of Drs. Sambon and Low, I instituted two experiments which dispose for good and all of any objections that otherwise might have been advanced against the theory. Drs. Sambon and Low, Mr. Terzi, their servants and visitors, lived for the three most malarial months of 1900 in one of the most malarial localities of the Roman Campagna —Ostia—in a hut from which mosquitoes were excluded by a simple arrangement of wire gauze on the doors and windows. They moved freely about in the neighbourhood during the day, exposed themselves in all weathers, drank the water of the place, often did hard manual work, and beyond retiring from sunset to sunrise to their mosquito-protected hut observed no precautions whatever against malaria. They took no quinine. Although their neighbours, the Italian peasants, were each and all of them attacked with malaria, the dwellers in the mosquito-proof hut enjoyed an absolute immunity from the disease. Whilst this experiment was in progress, mosquitoes

fed in Rome on patients suffering from tertian malaria were forwarded in suitable cages to the London School of Tropical Medicine, and on their arrival were set to bite my son, the late Dr. P. Thurburn Manson, and Mr. George Warren. Shortly afterwards both of these gentlemen, neither of whom had been abroad or otherwise exposed to malarial influences, developed characteristic malarial fever, and malarial parasites were found in abundance in their blood both at that time and on the occurrence of the several relapses of malarial fever from which they subsequently suffered.

The mosquito-malaria theory has now, therefore, passed from the region of conjecture into that of fact.

THE MALARIA PARASITE IN THE MOSQUITO

(*See Fig.* 11)

In the lumen of the stomach: travelling vermicule stage.—When crescent-containing blood has been ingested by certain species of mosquito which belong to the Anophelinæ,* those crescents that are mature, and that are not obsolescent, are transformed into the two types of sphere already described—hyaline and granular; that is, male and female. The hyaline spheres then emit their filaments or microgametes, which, breaking away, approach and seek energetically by butting and boring to enter the granular spheres. At one point on the surface of each of the granular spheres a minute papilla is projected to meet, as it were, a corresponding attacking microgamete. At this point one of the latter contrives to enter, and, after momentarily causing considerable perturbation in the contents of the sphere, comes to rest and vanishes from view. Although the granular sphere may be subsequently energetically attacked, no second microgamete can effect an entrance. For a short time after this act of impregnation† the granular sphere or

* So far, this is the only kind of mosquito which has been found an efficient insect host for the parasite.

† The impregnation of the granular sphere has only twice been witnessed in the case of the malaria parasite of man (MacCallum); but in hæmoproteus of birds it has been observed many times. Koch has seen the resulting travelling vermicule in the plasmodium of sparrows. Analogy, therefore, justifies the inference, so compatible with the other well-ascertained features in the cycles

macrogamete undergoes no apparent change. Presently, however, it gradually alters in shape, becoming oval, elongated, and finally assuming a lanceolate and then a vermicular form, the hæmozoin accumulating at the broad or posterior ends whilst the anterior end becomes pointed and hyaline. On the completion of these changes, the little body begins to move about; at first slowly, then more rapidly, the pointed end being in front. Should this travelling vermicule, technically known as an *oökinete*, impinge on a blood corpuscle, white or red, it passes through it.

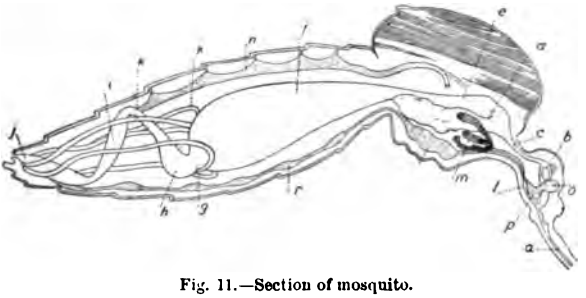


Fig. 11.—Section of mosquito.

a, Mouth; *b*, pumping organ; *c*, œsophagus; *d*, homologue of proventriculus *e*, anterior part of midgut; *f*, midgut; *g*, pylorus; *h*, pyloric diverticulum; *i*, hindgut; *j*, rectum; *k*, Malpighian tubes; *l*, salivary duct; *m*, salivary gland; *n*, dorsal vessel; *o*, supra-œsophageal ganglion; *p*, sub-œsophageal ganglion; *q*, conjoined ganglia; *r*, abdominal ganglia.

Dissection of the mosquito.—To follow the evolution of the malaria parasite the student, by frequent dissection, should first familiarize himself with the normal appearance of the internal organs of the mosquito. The following method of obtaining and mounting the organs for microscopical examination is that taught by Dr. Daniels at the London School of Tropical Medicine: Having killed the mosquito by chloroform, tobacco smoke, etc., with a mounted needle transfix the thorax, and with the fingers pull off the legs and wings one by one, being careful to pull them obliquely from the needle. The body of the mosquito should then be placed in a drop of normal saline solution on a glass slide. Then flatten

of the intracorpuscular parasites of man and the lower animals, that a similar arrangement obtains in the Plasmodidæ of man. Prof. Grassi showed me sections of the mosquito's stomach in which the travelling vermicules could be seen approaching and actually in contact with the epithelial coat. These preparations were from mosquitoes killed thirty-two hours after feeding on malarial blood.

out a little the posterior end of the abdomen, and nick it on each side about the junction of the penultimate segment; a weak place in the exoskeleton is thus formed. The thorax being now fixed with one mounted needle, another needle placed flat on the last segment of the abdomen steadily drags this away from the rest of the mosquito. The stomach or midgut and Malpighian tubes can thus be gradually pulled out from the exoskeleton; when sufficient length of œsophagus comes into view it can be divided by a touch of the needle. The ovaries of the female and testes of the male are also pulled out with the stomach. Sometimes the stomach is found to be full of blood or other food; in this case it is necessary to make a nick in the stomach: the weight of the cover-glass, which should now be applied, by its gentle pressure may express the blood. Occasionally it is necessary to wash the blood away, by allowing the stomach to refill with saline solution and then pressing on the cover-glass, and repeating the process as often as may be necessary.

The salivary glands, lying in the prothorax, can sometimes be obtained by pulling them out in dragging off the head. This method should be avoided if possible, as the glands are difficult to separate from the head, and it is impossible to compress the head without crushing the eyes; the pigment thus set free interferes with a microscopical examination. The simplest and most certain method of procuring the salivary glands is, after *cutting* off the head, to divide the thorax obliquely, so that its anterior portion, including the attachments of the anterior and middle pair of legs, is separated from the rest of the trunk. This portion contains both salivary glands. The exoskeleton should then be broken up with needles into five or six pieces in normal salt solution. A cover-glass is applied and steady pressure exercised with the point of the needle over each fragment of the exoskeleton. In this manner the glands are separated from the chitinous fragments, and can be readily examined. In the majority of dissections at least five out of the six lobes will be exposed undamaged.

In the stomach wall: encysted or zygote stage (Fig. 12).—This newly acquired power of locomotion and penetration on the part of the fecundated parasite, together with other well-ascertained facts, justifies the presumption that soon after its formation the travelling vermicule, now known as an oökinete, penetrates the wall of the mosquito's stomach. Working its way through the layer of cells and the delicate basement membrane which together constitute the inner coat of this organ, it finally lodges itself among the longitudinal and transverse muscular fibres lying between this inner membrane

and the equally delicate outer coat. Here the parasite, some thirty-six hours after the mosquito has fed, may be detected as a minute (6 μ) oval or spherical body with a sharp outline and hyaline or slightly

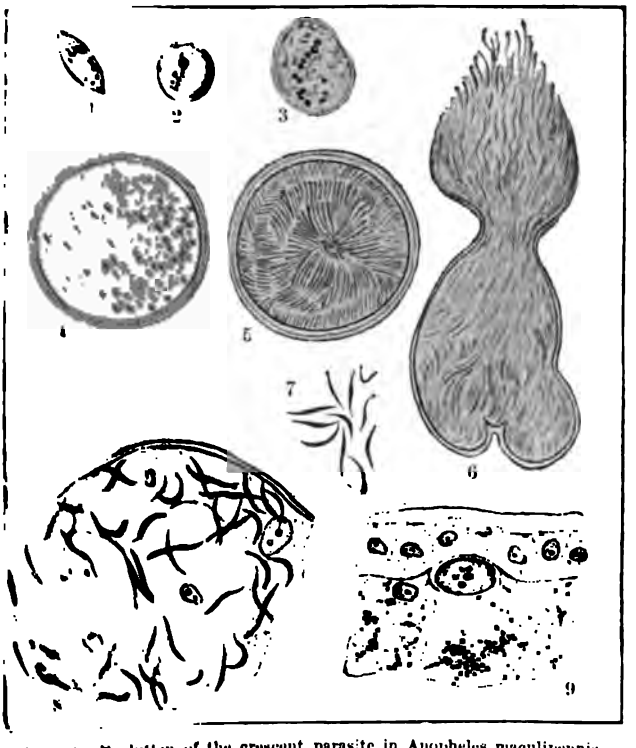


Fig. 18. Evolution of the crescent parasite in Anopheles maculipennis. (*Adapted from Grassi, Bignami, and Bastianelli.*)

1 to 6. The parasite as found in the stomach wall; 7, isolated sporozoites; 8, sporozoites in the salivary gland; 9, section of stomach wall showing the parasite as a cyst.

granular contents in which the hæmozoin particles are plainly visible. It lies between the muscular fibres, which, as it grows, it dissociates to a certain extent.

During the next few days the parasite increases rapidly, acquiring a well-defined capsule, and, in

consequence of its growth, protruding on the surface of the insect's stomach like a wart or wen (Fig. 13). Meanwhile, important changes take place in the interior of the parasite, which has now acquired a spherical contour and has attained the stage of development to which the term oöcyst is applied. Nucleus and protoplasm divide into a number of spherular daughter cells, around which, attached by one end like the spines on a porcupine, a vast number of minute (16 μ), slender, spindle-shaped, nucleated bodies are ultimately formed. At a later stage the spherules disappear, leaving the

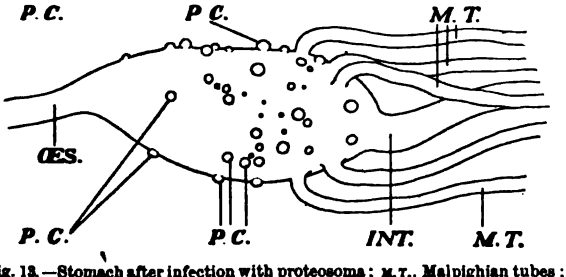


Fig. 13.—Stomach after infection with proteosoma: M.T., Malpighian tubes; INT., intestine; ŒS., œsophagus; P.C., proteosoma zygotes protruding into the body cavity.

spindles (sporozoites) loose in the capsule, which is now packed to bursting point. In about a week—sooner or later according to atmospheric temperature, which has a great influence on the rate of development of the parasite—the capsule ruptures and collapses, discharging its contents into the body cavity of the mosquito.

In the salivary gland: sporozoite or infective stage.—From the body cavity of the mosquito the spindle-shaped sporozoites pass, probably by way of the blood, to the three-lobed salivary glands lying one on each side of the fore part of the thorax of the insect (Figs. 11, *m*, and 14, B). These glands communicate with the base of the mosquito's proboscis by means of a long duct, around the radicles of which the clear, plump cells of the gland are arranged. The sporo-

zoites can be readily recognized in many (Fig. 12, s), though not in all, of the cells, especially in those of the middle lobe, and also free in the contents of the ducts. So numerous are they in some of the cells that the appearance they present is suggestive of a bacillus-laden lepra cell.

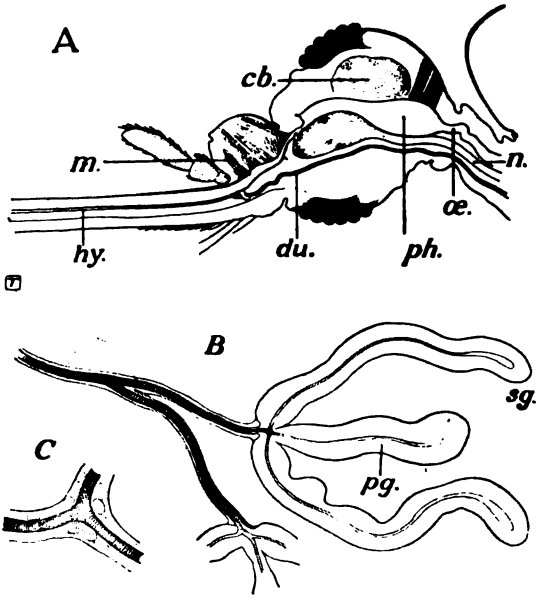


Fig. 14.—Dissection of head of mosquito.

A, Median section of head, showing *du*, the veneno-salivary duct, with its insertion in *hy*, the hypopharynx; *cb*, cerebrum; below this are the cerebellum and the pumping enlargement of œ, the œsophagus; *m*, muscle; *n*, nerve commissure. The other parts have been removed. B, the veneno-salivary duct, showing its bifurcation and the three glands on one of its branches; *pg*, poison gland; *sg* marks the upper of the two salivary glands. C, The bifurcation of the duct with its nucleated hypodermis.

Transference to the Human Host

By a large number of experiments, abundantly confirmed, Ross distinctly proved that if appropriate birds are bitten by mosquitoes whose salivary glands contain the sporozoites of the avian plasmodium, the birds become infected with the parasite, and in

due course show it in their blood and develop corresponding clinical symptoms. And now many experiments, some of which have been alluded to, have clearly

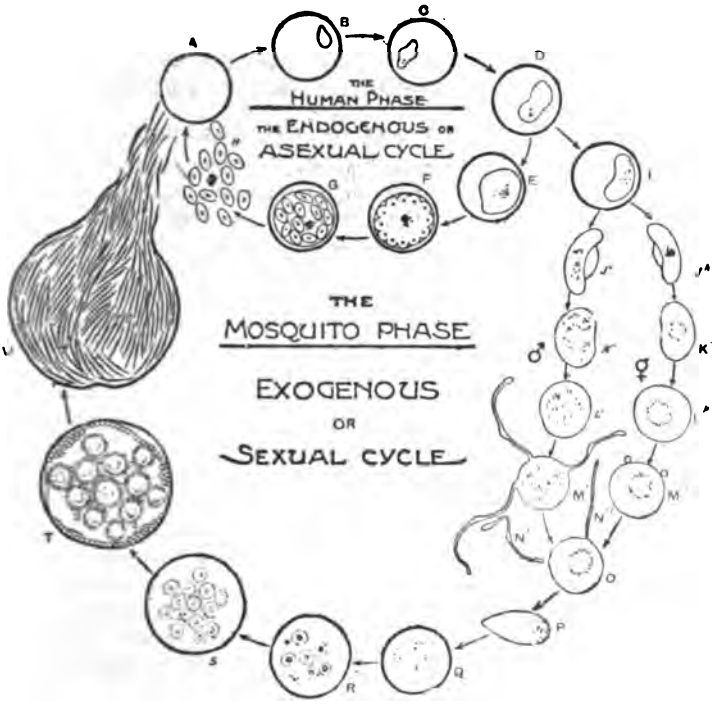


Fig. 15.—Schema showing the human and mosquito cycles of the malaria parasite. Modified from Blanchard's diagram illustrating life cycle of Coccidium schubergi. (*From the Malaria Number of the "Practitioner," March*, 1901.)

A, Normal red cell; B, C, D, E, red cells containing amœbulæ or myzopods; F, G, H, sporocytes; I, young gametocyte; J′, K′, L′, M′, microgametocytes or male gametes; J″, K″, L″, M″, O, macrogametocytes or female gametes; N′, N″, microgametes; P, travelling vermicule; Q, young zygote; R, S, zygotomeres; T, blastophore; U, mature zygote.

shown that a similar process occurs in the evolution of the malaria parasite. If a mosquito whose salivary glands contain malarial sporozoites bites a man, the sporozoites are introduced into the blood,

penetrate the red corpuscles, and multiply. After eight to ten days their progeny can be seen as malaria parasites of the type corresponding to those of the man on whom the infecting mosquito had originally fed. Schaudinn, by diluting blood with blister serum and introducing into the mixture the salivary glands of a malaria-infected mosquito, was enabled to witness the entrance of the sporozoites into the red corpuscles.

Complete Cycles of the Parasites

The complete cycles (Fig. 15), therefore, both intra- and extracorporeal, of the endocorpuscular blood parasites of man and birds can now be described. Using the most generally adopted zoological terms, and commencing with the youngest phase, these parasites may be described as entering the blood-corpuscles as *sporozoites*. Growing at the expense of the hæmoglobin they become pigmented and, on reaching maturity, develop either into (*a*) *schizonts* (the segmenting body—rosette body), or into (*b*) *gametocytes* (crescents, spherical bodies of tertians or quartans).

(*a*) The *schizonts*, after concentration of hæmozoin, divide into a number of naked segments or *merozoites*, which, on the breaking down of the enveloping blood corpuscle, escape into the blood plasma and enter fresh blood-corpuscles; thus completing the *endogenous cycle* and providing for the multiplication of the parasite in the vertebrate host. The process of reproduction in this the *asexual cycle* is called *schizogony*.

(*b*) The *gametocytes*, or *gametes*, as they are usually termed, belong to the *exogenous* or *sexual cycle* passed in the bodies of particular species of mosquito. They are of two kinds: *male* (hyaline crescents or spheres) and *female* (granular crescents or spheres). The male gametocyte emits several *microgametes* (flagella), one of which, breaking away, enters and impregnates the single *macrogamete* of which the female gametocyte consists. The product is a *zygote*, which, acquiring locomoting powers, becomes an *oökinete*, and transfers itself from the lumen to the wall of the

middle intestine (stomach) of the mosquito in which it had developed. Here it comes to rest and is soon surrounded with a capsule. It is now an *oöcyst.* Presently it divides into a number of daughter cells and *residual bodies.* The former produce a vast number—as many as ten thousand in a single oöcyst—of minute bodies, the *sporozoites* (zygotoblasts, germinal rods—Ross). Finally the oöcyst ruptures, discharging the sporozoites into the body cavity of the insect, whence they are transferred to the salivary glands, in the secretion of which, opportunity offering, they are injected into the blood of an appropriate vertebrate, whose blood corpuscles they subsequently enter, and, becoming schizonts, renew the cycle. The process of multiplication in this the sexual or exogenous cycle is called *sporogony.*

Latent phase.—It is a well-established fact that, concurrently with the subsidence of acute clinical symptoms, the malaria parasite may disappear from the general circulation. This it does either spontaneously or as a result of the administration of quinine. In the majority of instances the disappearance is only temporary. Usually, after an interval of weeks or months, the parasite reappears in the general circulation and there is a renewal of the clinical phenomena. As to the organ or tissue it selects, or as to its appearance and structure during this time of latency, or as to the exact conditions which cause it once more to resume active, propagating, circulating life, nothing is positively known.

Three opinions, each of them founded on a certain amount of fact, have been advanced on this point: (*a*) That the parasites, when the conditions become unfavourable for schizogony, become encysted and lay up in the spleen or other organ. (*b*) That they never completely leave the circulation, but continue to propagate in the usual way, though in numbers so small that it is practically impossible to find them even by prolonged microscopical examination. (*c*) That certain sexual forms (macrogametes), a phase of the parasite apt to persist for prolonged periods in the blood, forms parthenogenetically and while still i

the circulating blood asexual spores (merozoites), which, on liberation, enter the red blood-corpuscles and so renew the asexual, intracorporeal phase. This much we do know—namely, that physiological strain or vital depression in the host tends to bring about conditions which break up, and that quinine and vital vigour tend to bring about conditions which favour, latency.

Possibility of yet another Phase

So far the story of the life-history of these parasites seems to be complete. There are certain facts, however, which seem to indicate the possibility of yet another phase, or of etiological factors which hitherto have escaped observation. First, there are districts in India, Africa, and elsewhere that are practically uninhabited on account of the prevalence and virulence of the local malaria. If man be necessary for the completion of the life-cycle of the parasite, how explain its abundance in such circumstances—that is to say, in the absence of man? Second, those engaged in malarious districts on works entailing disturbance of the soil, e.g. opening jungle lands, digging canals or foundations, making roads or railways, are particularly prone to contract malaria; yet such operations at first sight seem in no way calculated to foster broods of malaria-infected mosquitoes. How account for infection in such circumstances? where, and in what form, is the malaria germ to be found there?

Of the first of these difficulties two explanations may be submitted. (*a*) The malaria parasite may be capable of living in a variety of animal hosts, as we know to be the case with the hæmoprotozoa of birds and many other and more highly organized animal parasites; and it may be that in the malarious districts alluded to the prevalence of such an appropriate host, together with the presence of an appropriate mosquito, ensures the continuance and abundance of the parasites. Support is given to this hypothesis by Dionisi's discovery of intracorpuscular parasites in bats, closely resembling

the malaria parasites of man; and by a similar discovery by Koch in monkeys. Similar parasites have also been found in the ox, sheep, dog, and horse. (*b*) The malaria parasite may be capable of passing from mosquito to mosquito without the intervention of a vertebrate, by passage of the sporozoite into the mosquito's eggs. We have the support of analogy for this hypothesis. Several *Babesiæ*, such as *Babesia bovis*, which gives rise to hæmoglobinuric fever (Texas fever) in cattle, and *Babesia canis*, which causes the malignant jaundice of dogs, are transmitted in this way. The intermediary, a tick, takes in the parasite with the blood it sucks from an infected animal. The parasite, probably after undergoing developmental changes, then passes into the egg of the tick, and so to the young tick hatched out from the infected egg; and it is this young tick that implants the germ into the next vertebrate host. In the case of the trypanosoma of the little owl, Schaudinn claimed to have shown that it may enter the eggs of the intermediary mosquito and that the infection may in this way be transmitted, not only by the mosquito that sucked the trypanosoma-containing blood but also by its progeny.

Most observers are now of opinion that the malaria parasite, under natural conditions, can be acquired by man only through the bite of the mosquito; that the mosquito can acquire the parasite only by ingesting the blood of a malaria-infected man or, possibly, other mammal; that there is no extracorporeal life other than that described; that there is no authentic instance of malaria being acquired in uninhabited places; that in the case of malaria in connection with soil disturbances, it depends on the creation during digging operations of puddles of water in which mosquitoes breed; and that its epidemic occurrence under these circumstances is owing to unhygienic conditions, such as usually prevail when large bodies of men, some of whom may bring the infection with them, are brought together on public works attended with extensive earth cutting, as in railway, road, or canal making.

CHAPTER II

MALARIA: THE MICROSCOPICAL EXAMINATION OF THE BLOOD

BEFORE commencing the study of malarial blood it is advisable for the beginner to familiarize himself with the microscopical appearances of normal blood, both in fresh and stained preparations. He should learn to recognize the several varieties of leucocyte; to appreciate differences in colour, size, and shape of the red cells; to recognize dirt, vacuoles, forms of crenation, and artificially produced appearances. By mastering such details at the outset important sources of fallacy will be avoided, and in the process of self-education a useful knowledge of technique will be acquired.

For a thorough appreciation of the principles on which blood examinations for the demonstration and study of the malaria parasite should be conducted, it must be borne in mind that the parasite is intra-corpuscular. To see it, therefore, it is necessary, particularly for the beginner, so to dispose the corpuscles in the preparations that a proportion of them shall lie flat on the slide, in a single layer, and presenting their surfaces, and not their edges, to the observer (Fig. 16). It is mainly from ignoring this fundamental principle that so many fail to find the parasite.

Preparation of fluid blood films.—To secure this disposition of corpuscles in fresh blood the following procedure, the smallest details of which must be scrupulously carried out, is recommended :—

Thoroughly cleanse with alcohol three or four thin cover-glasses and as many slips, and cover them immediately with some convenient vessel so as to protect them from the minutest particle of floating dust. Cleanse one of the patient's finger-tips with alcohol and dry it. Prick the part with a clean needle, and wipe away the first drop of blood that

exudes. Then gently, with finger and thumb, squeeze the finger-pad and express a second minute droplet of blood; this should be very small—no larger than a pin's head. Touch the droplet lightly with the centre of a cover-glass, taking care that the latter does not come into contact with the skin, and immediately drop the cover-glass on the slide. No pressure should be used to cause the blood to spread out. If glasses and skin are quite clean, the blood will at once run out in a

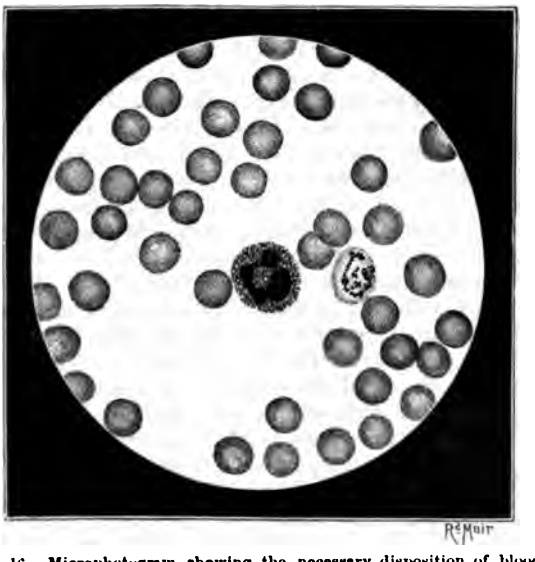


Fig. 16.—Microphotogram showing the necessary disposition of blood-corpuscles in slides for examination for the plasmodium. To the right of the white blood-corpuscle in the centre of the field a red blood-corpuscle three-fourths filled with a tertian parasite is visible. (*From microphotogram by Dr. Cosens.*)

very fine film. It is sometimes more convenient to obtain the blood from the lobe of the ear or, in children, the great toe.

Several preparations should be made, the requisite blood being obtained by renewed gentle compression of the finger-tip.

After waiting a few minutes to allow the blood to spread out completely between the glasses, it is well to ring the preparations with vaseline. This will effectually stop all movement, all evaporation of

the blood, and, consequently, over-compression of the corpuscles, and will thereby greatly facilitate examination.

In making these preparations care should be taken to sterilize the needle employed, otherwise grave accidents might occur. It is, of course, unnecessary to sterilize the slides and cover-glasses.

Characteristics of a successful preparation.—On holding a successful preparation up to the light, one or more areas, each made up of three zones, the different zones shading into each other, can be made out by the naked eye. Each such area includes a peripheral zone of a reddish tinge, a middle zone having a somewhat iridescent look, and a central zone absolutely devoid of colour. Successful preparations may be recognized by the presence of these zones. Preparations not exhibiting this appearance should be rejected; it is waste of time to examine them.

On examining successful preparations with the microscope it will be found that the central zone or area contains few or no blood-corpuscles. This zone may be designated the "empty zone." Proceeding outwards from this we come on an area occupied by scattered, isolated, compressed, and much-expanded corpuscles — the "zone of scattered corpuscles." Farther out the corpuscles become more numerous and less expressed (Fig. 16). Gradually, as we trace the film still farther outwards, the corpuscles are found approximated to each other, until, finally, the peripheries of the corpuscles are mostly in touch —the "single-layer zone." Farther out the corpuscles, though still lying flat, are found to overlap each other or are piled one on the top of the other—the "zone of heaped-up corpuscles." Beyond this zone the corpuscles are arranged in rouleaux—the "zone of rouleaux." At the extreme margin of the preparation the corpuscles tend to break up and run together so as to form a narrow border of free hæmoglobin, the individual corpuscles perhaps being indistinguishable—the "zone of free hæmoglobin." Each of these zones should be studied, for each may afford special information about the malaria parasite.

Microscopical examination.—The beginner will save time if he gets someone who is familiar with the necessary technique, and with the appearance of the parasite in the blood, to give him one or two lessons. Accuracy and quickness can be acquired only by practice. It is a good plan to practise preparing films from one's own blood.

The examination is best conducted with a $\frac{1}{12}$-in. oil immersion lens, a rather low eyepiece, a substage condenser, and a good but not too dazzling illumination. It is practically useless to work with any objective lower than $\frac{1}{12}$ in., or without a substage condenser.

It is not always possible to choose, but, if practicable, a case of quartan infection should be selected for examination in the first instance. Failing a quartan, a well-defined benign tertian infection might be chosen. Failing either of these, a long-standing case of recurring malaria with marked cachexia will afford the next best opportunity. It is best to examine the patient's blood just before or at the time of rigor. In quartans and benign tertians, at the time named, there should be little difficulty in discovering large parasites; in the case of these infections attention is called to the relatively large parasites by the abundance of coarse pigment they contain. In the blood of malarial cachectics with recurring febrile attacks it is generally an easy matter to find crescents and crescent-derived spheres, as this form of the parasite is of considerable size, carries abundance of pigment, and possesses a very definite and striking shape.

When the beginner has learnt to recognize the larger forms of the parasite, he will have begun to appreciate what sort of body he has to look for; thereafter he should be able to educate himself, and to pick out the smaller and intermediate forms.

In proceeding to make his first examination of a liquid blood slide, the beginner, in the first instance, should confine his attention to the "single-layer zone." Field after field of this he must pass in review, carefully scrutinizing the interior of every

blood corpuscle, every leucocyte, and every pigmented body, even though it be not included in a corpuscle. He must not expect to find parasites in every corpuscle, or even in every field; and he certainly must not expect, as the beginner usually does, to find in every slide the beautifully regular segmenting form or "rosette body" or the weird-looking flagellated body made familiar to us by so many illustrations. Such bodies, though really present somewhere and in some form at one time or another in every case, are among the least common of the many phases of the malaria parasite; they are met with only under very definite and not very constantly encountered conditions, and are not very often seen at an ordinary clinical examination.

In most cases the parasite is discovered in the first field or two examined; but in not a few instances dozens of fields may have to be scrutinized before a single parasite is found. Therefore no examination can be said to be complete, in a negative sense, until at least half an hour has been spent over several suitably prepared slides.

The intracorpuscular forms most frequently met with have the appearance either of small specks of pale protoplasm, or of larger masses of pale protoplasm containing grains of black pigment. Close watching discovers that the former are endowed with amœboid movement, and that they continually change shape and position in the affected corpuscles. As these movements are an important test of the parasitic nature of the body sought, they should be carefully looked for. The smallest protoplasmic specks look like washed-out smudges of dirty-white paint, half hidden by the hæmoglobin; they are sometimes hard to see. Their parasitic nature can readily be determined by their movements; by their soft, ill-defined margins; and by the fact that they tend now and again, on first removal from the body, and permanently later, to assume the appearance of tiny white rings which show up very distinctly in the hæmoglobin of the corpuscle. These features readily distinguish them from the sharply defined, clear,

motionless, non-parasitic vacuole (Fig. 17). The other common forms—the larger or smaller intracorpuscular pigmented parasites—occupy anywhere from a sixth to nearly the entire area of the affected corpuscles. They are recognized by their pale protoplasm; by the black hæmozoin particles scattered about or, if towards the period of rigor, concentrated in their interior; and by their more or less active amœboid movements. In quartans and tertians, but especially in the former, segmenting rosette forms are seen occasionally.

Examination of blood for flagellated bodies.—When the student has become familiar with these appearances, and has thoroughly seized the fact that the segmenting forms are to be found only or usually during, just before, or soon after the rigor stage of fever, he should endeavour to follow up the initial steps of the exogenous, sexual or mosquito phase of the parasite. So far as ordinary preparations permit, this phase is best studied in the "zone of heaped-up corpuscles" and in the "zone of rouleaux"; because in these zones the parasite, not being subjected to pressure, has more freedom to undergo its evolutionary change into the flagellated body.

In ordinary quartans and tertians flagellated bodies are but seldom encountered. The best time to find them in such cases is said to be during the hot stage of the fever. In cases of crescent infection they are much more frequently met with, as, in this form of malaria, flagellated bodies are usually more numerous, appear at any time of the clinical cycle, and persist in the circulation perhaps for several weeks after fever has disappeared.

In most cases of crescent infection the gradual evolution of the flagellated body from crescent through oval and sphere can, with patience, be easily followed.

Diagnostic value of the "zone of free hæmoglobin."—The zone of free hæmoglobin is of value as enabling the practised observer to pronounce very rapidly on the presence or absence of pigmented parasites in the blood. The relatively large quantity of blood in each field of this zone, and therefore the

proportionally large number of parasites in any given field, lends itself to this, as does the fact that the hæmozoin shows up very distinctly in the homogeneous sheet of free hæmoglobin.

Phagocytosis and pigmented leucocytes.—Striking examples of phagocytosis are often witnessed in malarial blood. So soon as a malarial parasite, whether spontaneously or as a result of pressure, escapes from the blood-corpuscle in which it had developed, it becomes exceedingly liable to attack by the phagocytes. More especially is this the case with the flagellated organism; this body seems to have a powerful attraction for the phagocytes, which are often seen to travel long distances to attack it.

Pigmented leucocytes—that is to say, leucocytes containing grains or blocks of hæmozoin—are very often encountered; they can best be seen in the single-layer zone during, or shortly after, fever. Leucocytes may sometimes be observed to include the hæmozoin set free by the falling to pieces of the segmented parasites. Often they derive their hæmozoin from the remains of some sphere or flagellated body which they may have engulfed subsequently to the preparation of the slide. In peripheral blood the phagocytes are rarely, if ever, seen to attack the parasite so long as it is inside a blood-corpuscle.

Both the large mono- and, very rarely, the polynucleated leucocytes may contain malarial pigment. Care, however, must be exercised in drawing conclusions from the discovery of black material in these bodies; in imperfectly cleaned slides, fragments of dirt, which the leucocytes rapidly take up, are apt to mislead.

Pigmented lymphocytes.—According to Metchnikoff, the lymphocyte has no phagocytic action in malaria. This observation I believe to be correct. Several writers, however, have described and figured what they regard as malarial pigment in the lymphocyte. This, I am convinced, is founded on an error in interpretation, and has arisen from ignorance of the fact that in all bloods, healthy and malarial alike, from 20 to 50 per cent. of the small mononucleated lymphocytes contain, lying in the narrow zone of

cytoplasm, one or two minute round dots of intensely black material optically indistinguishable from hæmozoin. I am not aware that this appearance has been described hitherto, but multiplied observation has convinced me of the accuracy of my statement. The discovery, therefore, of what looks like a speck of intensely black pigment in the lymphocytes must not be regarded as evidence of malarial infection.

Diagnosis of vacuoles.—The beginner may have a difficulty in determining whether certain appearances in the corpuscles are vacuoles, or whether they are parasites. The following hints may help him to

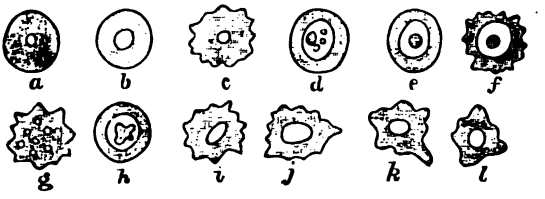


Fig. 17.—Vacuolated and crenated blood-corpuscles. (*After Laveran and Blanchard.*)

a, b, c. Blood-corpuscles with central vacuoles, *c* is crenated; *d, e, f, h,* blood-corpuscles with central vacuole containing fragmented hæmoglobin. Sometimes minute eye-shaped vacuoles with a speck of hæmoglobin in the centre are met with, and are apt to be taken for parasites. *g.* Crenated blood-corpuscles with several vacuoles, or, it may be, crenations out of focus; *i, j, k, l,* deformed blood-corpuscles with central lacunæ.

a correct decision: Vacuoles (Fig. 17, *a, b, c, d, e, f, h, i, j, k, l*) are well defined, clear, and have sharp edges; they may change form slightly, but they have no true amœboid movement, carry no pigment, and, of course, do not stain. Intracorpuscular malaria parasites, on the contrary, are dim and, as a rule, ill defined; they have soft, shaded-off edges; possess amœboid movements; when large they carry hæmozoin grains; and, of course, they take the appropriate stains. It is hardly necessary to indicate the points of diagnosis from leucocytes, or from cupped, folded, or crenated (Fig. 17, *c, f, g, i, j, k, l*) corpuscles.

Moribund and fragmented parasites.—Moribund—it may be fragmented—free parasites (Fig. 18) are

often a source of confusion to the beginner. Their nature is frequently misunderstood; they are sometimes erroneously termed "sterile bodies," an expression at one time frequently applied to the crescent-derived spheres (gametocytes). They are, in fact, mechanically-freed parasites expressed from blood corpuscles by the compression to which the blood is subjected between slip and cover-glass. The longer blood is on the slide—particularly if evaporation be not prevented by vaseline-ringing of the cover-glass—the more closely will the cover-glass approximate to the slip, the greater will be the pressure on, and consequent thinning and spreading out of, blood-corpuscles and parasites, and the greater the liability to damage of these very delicate

Fig. 18.—Degenerating vacuolated plasmodia.

bodies. Frequently the artificially-freed parasites are broken into small fragments. The entire, as well as the fragmented parasites, on becoming free in the liquor sanguinis, tend to assume a spherical or disc-like form; at the same time the protoplasm of which they are composed seems to become diffluent, and the hæmozoin is resolved into a number of minute dust-like particles possessing active, brownian movement. Some of the spherical or disc-shaped bodies with dancing hæmozoin particles are really crescent-derived spheres or other forms of gametes. These are parasites which have escaped from corpuscles in a normal way, but which have become arrested in their evolution in consequence of the abnormal conditions in which they are placed *in vitro*; others are the remains of flagellated bodies, the microgamete filaments having broken away.

The parasite as a means of diagnosis.—All of these multiform appearances the student must learn to recognize and interpret. Skill in this is merely a matter of time, practice, and reflection. Given these, the student should be able not only to diagnose by the microscope malarial infection, but also to recognize the type of any particular infection, the period of the fever cycle, and, it may be, the severity of the case. For diagnosis in malaria, therefore, skill in the microscopical examination of the blood is of the utmost value, and no pains should be spared by the practitioner in malarious countries to acquire it. In acute untreated malaria the parasite may be detected practically in every case. Thus in 616 cases Thayer and Hewetson—except in two or three instances where the patient's blood was examined only during convalescence—found it in every instance. The best authorities are equally emphatic on this point. Personally, I can assert that since I became familiar with the subject I have never failed to find the parasite in any acute untreated malarial case I have had a proper opportunity of examining. Whenever in a case of acute disease, supposed to be malarial, I have failed to do so, the case has turned out to be of quite another nature.

Bearing of quinine on microscopical diagnosis.—It is of little use to examine the blood for the intracorporeal forms of the malaria parasite after full doses of quinine have been taken; the drug rapidly brings about the disappearance of this phase of the parasite. The crescent alone is unaffected by drugs, and in suitable cases may be found for days after the patient is cinchonized.

On staining malarial blood.—As a general rule, the beginner should work only with unstained preparations of fresh liquid blood. To the unpractised, staining is full of pitfalls. In such circumstances it must not be relied on for purposes of responsible diagnosis. To the experienced microscopist and diagnostician, and for the study of the morphology of the parasite, staining is of the highest value; moreover, some such method must be employed sho

permanent preparations be desired, or should it be inconvenient to make an immediate examination of the blood. Many methods have been devised; here only one or two can be given.

Preparing the film.—It is usual to spread the blood on cover-glasses; for many reasons I prefer to spread it on slips. There are various ways of preparing the films; the following I can recommend:—

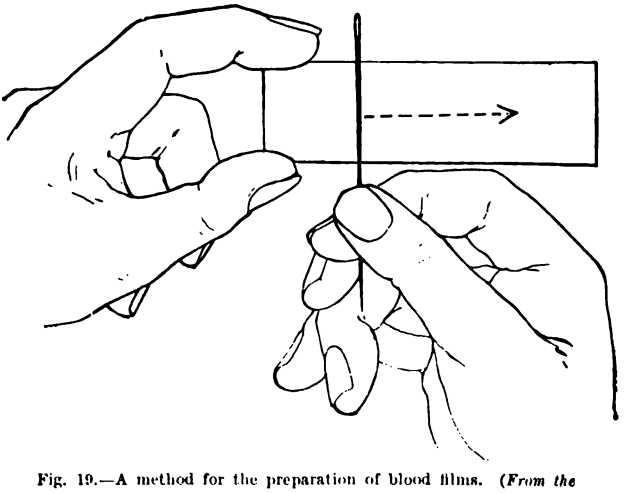


Fig. 19.—A method for the preparation of blood films. (*From the Malaria Number of the "Practitioner," March*, 1901.)

Probably the easiest, as well as the quickest and most convenient, is a modification of that recommended by Christophers and Stephens. Prick the cleansed finger-pad or lobe of the ear, and express a droplet of blood. Take this up by touching it lightly with a clean glass slip about an inch from one end of the slip. Across the slip and on the blood lay the shaft of the needle—an ordinary straight, rather long sewing needle (Fig. 19). Pause for several seconds until the blood has run out by capillarity between the needle and the slip; then, holding it by one end, push the needle over the face of the slip in the direction of the length of the latter, so as to spread the blood over the entire breadth of the middle third of the slip. By passing the soiled needle through the lapel of the coat, the operator can cleanse it quickly and be ready to make, by a repetition of the manœuvre, a series of films from the same puncture.

Or: Take up the droplet of finger blood on the edge of the end of a slip; lay this at an angle of about 45° across another slip held horizontally; pause till the blood has run out along the line of contact of the two glasses, and then glide the inclined slip along the surface of the horizontal slip in a direction away from the acute angle. According as the angle formed by the two slips is less or more acute will be the thinness of the film.

However spread, after the blood has dried, whenever it is desired to stain it, either at once or at any future and more convenient time, it should be "fixed" by dropping on the film a little absolute alcohol and ether in equal parts, or absolute alcohol alone. Cover-glass films may be dropped into a small wide-mouth bottle containing the fixing agent, or they may be fixed by passing them through the flame (not a good method), or by placing them for some hours (one to three) in a warm dry chamber at a temperature of 105° to 120° C. When alcohol is used, after ten to thirty minutes or longer it must be dried off before staining.

Stains

The stains usually employed belong to two categories: (*a*) those which stain the protoplasm and the nucleus the same colour; (*b*) those which, by tinting them differently, differentiate the protoplasm from the nucleus.

(*a*) Of the former I would recommend the following:—

Borax-methylene blue.—A drop or two of aqueous solution of borax- (5 per cent.) methylene blue (2 per cent.) is spread on the film. After thirty seconds or less the slide is thoroughly washed in water, dried with filter paper, and afterwards by gently warming over the spirit-lamp. Finally, xylol balsam and a cover-glass are applied.

Löffler's methylene blue.—Concentrated alcoholic solution of methylene blue 30 parts, solution of caustic potash ($\frac{1}{10000}$) 100 parts. Stain for thirty seconds, wash in water, dry and mount.

Carbol-thionin.—Saturated alcoholic (60 per cent.) solution of thionin 20 parts, watery solution (2 per cent.) of carbolic acid 100 parts. The mixture should be kept at least a fortnight before use. Stain for five minutes, wash and mount.

Hæmatoxylin and eosin.—Ehrlich's acid hæmatoxylin, or strong solution of hæmalum, five minutes; weak eosin, half

a minute; wash in tap water and then in distilled water dry and mount in xylol balsam. This is an easily carried out and effective method of obtaining less intensely stained but more permanent preparations.

(*b*) The many methods of obtaining differential staining of protoplasm and nucleus depend on the circumstance that, when solutions of certain kinds of methylene blue and eosin are mixed, a third red dye, with a special affinity for chromatin, is formed. They are all modifications of the original Romanowsky method. They are a little uncertain and troublesome to use, their success depending on the purity of the chemicals employed and careful attention to detail. The beginner is advised to become proficient, in the first instance, with the simpler methods given above. Having attained this, he should practise some form of the Romanowsky method, for, besides displaying the intimate structure of the malaria parasite, in consequence of the intense tinting of the nucleus which it effects it greatly facilitates the finding of the smaller forms of the parasite, not always an easy matter, especially in the case of the very minute young subtertian or malignant parasite. Of the three methods given below, Leishman's, everything considered, is the best. Both it and Jenner's method have the advantage of dispensing with preliminary fixing.

Romanowsky's method.—Cover-glass films are fixed by heat—110° C. for one hour. They are then immediately *floated* for over two hours on a freshly prepared mixture of saturated watery solution of methylene blue, 2 parts, and watery solution of eosin (1 per cent.), 5 parts, washed in water, dried and mounted. The precipitate formed by the mixture must not be filtered out.

Jenner's stain.—Special care must be taken that there is no trace of alkali or acid on the glass on which the film is spread; it must, therefore, be washed in distilled water and stood in absolute alcohol. The stain is made by dissolving Grübler's water-soluble eosin (yellow shade) and medicinal methylene blue in pure *absolute* methylic alcohol, which must be free from acetone and other impurities; the solutions are then mixed in the proportions of 125 parts of $\frac{1}{2}$ per cent. solution of the eosin, and 100 parts of $\frac{1}{2}$ per cent. solution of the methylene blue. Or the compound body formed by the eosin and methylene blue in this mixture may be purchased in the dry state and subsequently dissolved in absolute methylic alcohol.

To use the stain, a few drops are poured on the blood film and covered to prevent evaporation and precipitation. In three minutes, or a little longer, the stain is rapidly poured off, and afterwards the film is washed in *distilled* water from five to ten seconds until it assumes a pink colour. It is then dried high over the flame, or in the air, and mounted in xylol balsam.

Leishman's stain. — Two solutions are prepared. *A*, a 1 per cent. solution of medicinal methylene blue (Grübler) in distilled water, rendered alkaline by 0·5 per cent. sodium carbonate. Heat this to 65° C. for twelve hours, and allow it to stand at the room temperature for ten days. *B*, eosin, extra B.A. (Grübler), 1 in 1,000 of distilled water. Mix equal volumes of *A* and *B* and stand for six to twelve hours, stirring occasionally. Collect the flocculent precipitate in a filter, and wash with distilled water. Dry and powder the filtrate, which has a green metallic lustre, and contains the active ingredient of the Romanowsky stain. (This powder has been placed on the market, and can be procured in condensed tablets called *soloids*.) Make a 0·15 per cent. solution of the dye in methylic alcohol and keep in a stoppered bottle.

To use the stain, drop three to four drops of the solution on the unfixed blood film. After about half a minute to one minute or longer add six to eight or more drops of distilled water and mix them by moving about the slide. A precipitate forms at once in the water in successful slides. After five minutes or longer wash off the stain with distilled water, leaving a few drops of the water on the film for over a minute. Dry without heat, and mount in xylol balsam.

Eosin-azur stain, sold by Burroughs and Wellcome in tabloid form, is an azur stain of somewhat similar composition to that of Leishman. One tabloid is dissolved in 10 c.c. of pure methyl alcohol, and is usedas above; it gives similar but more brilliant results. It may also be used as Giemsa's stain dissolved in 5 c.c. of a mixture of equal parts of glycerine and pure methyl alcohol.

Giemsa's stain.—Azur II. eosin 3·0 grm., azur II. 0·8 grm., dried, powdered, and dissolved in 250 grm. of glycerine, to which are subsequently added 250 grm. of methyl alcohol; heat to 40° C. Shake the mixture and stand for twenty-four hours, and then filter.

Fix the films in methyl alcohol (three minutes). The staining solution is prepared by adding 1 drop of stain to 1 c.c. of distilled water at 30° to 40°. Immerse the film in this for fifteen minutes, wash in stream of water, dry, and mount in balsam.

Laveran's method for staining and preserving permanent preparations. The following solutions are required :—

Eosin, 1 : 1,000	4 c.c.
Distilled water	10 ,,
Bleu borrel *	1 ,,

* *Bleu borrel* is methylene blue and silver oxide. It is prepared as follows: In a 150 c.c. glass measure several crystals of

The mixture is placed in a Petri dish, the dried film is put in this and left from five to twenty minutes at about 37° C.; the slide should be placed on glass rods to prevent the formation of a precipitate. After staining, the preparation is washed with water, treated with a solution of tannin, washed again for a few minutes, and dried. The preparations are permanent, but keep better if unmounted.

Ross's thick-film method.—For the detection of small numbers of malaria parasites in the blood, and especially for the crescentic form, Ross recommends the adoption of thick films dehæmoglobinized in water. The parasites remain behind, clinging to the cell stroma. A drop of blood the size of a pin's head is dabbed on to a clean cover-glass so that an evenly spread smear results, about 5–7 mm. in diameter. After the dehæmoglobinized film has been dried in the air, it is stained in the ordinary way. The parasites are apt, however, to be greatly distorted by the action of the water.

Staining the flagellated body.—A sheet of thick blotting-paper, having rows of oblong holes (1 in. by $\frac{5}{8}$ in.) cut out in it, is prepared; it is slightly but sufficiently moistened with water, and laid smoothly on a sheet of window-glass.

A patient in whose blood the crescent form of the parasite abounds is selected. His finger is pricked and a droplet of blood, the size of a large pin's head, is expressed. A clean microscope slip is then breathed on once, and the droplet of blood immediately taken up by lightly touching it with the centre of the breathed-on surface of the slip. The blood is now rapidly and somewhat unevenly spread out with the needle so as to cover an area of about $\frac{3}{4}$ in. by $\frac{1}{2}$ in. The slip is immediately inverted over one of the blotting-paper cells and pressed down sufficiently to secure thorough apposition of the slip to the paper, without, at the same time, bringing the blood into contact either with the moistened paper forming the wall, or with the glass forming the floor of what is now a very perfect moist chamber. The rest of the paper cells are rapidly covered with blood-charged slips prepared in the same way. In from a quarter to three-quarters of an hour the slips are removed and dried by gently warming them over the spirit-lamp—blood surface away from the flame. When dry the films are fixed with absolute alcohol, a few drops being poured on each. After ten minutes the alcohol is dried off, and a few drops of weak acetic acid (10 to 20 per cent.) are laid on the films and left there long enough thoroughly to dissolve out all the hæmoglobin. The slides are then washed in water and dried. They may now be stained with various reagents. So far, I have obtained the best results from weak carbol-fuchsin (20 per

nitrate of silver are placed, and the measure is then filled with a concentrated solution of soda. The black precipitate of silver oxide is washed several times in distilled water, then a saturated solution of methylene blue (Höchst) is poured into the oxide and left in contact for fifteen days.

cent.) and prolonged staining. The stain is dropped on the slip and covered with a watch-glass; after six to eight hours it is washed off with water, the slide dried, and a cover-glass applied with xylol balsam.

On examining with a twelfth immersion lens slides prepared with methylene blue,* the nuclei of the white corpuscles are seen to be very deeply stained, the protoplasm of the white corpuscles is very lightly stained, whilst the parasites are stained an intermediate tint, and show up sharply enough in the faintly tinted red blood-corpuscles (Figs. 2, 16, 20). Contrast staining with eosin is uncertain in its results in methylene-blue preparations; even in practised hands good preparations are the exception. For ordinary purposes I do not recommend it; it is superfluous, troublesome, and unreliable.

On examining successful slides prepared by any of the Romanowsky methods, the red blood-cells will be found to be stained pale pink or greenish; the polynuclear leucocytes will show nuclear network ruby-red, the margins of the nuclei being sharply defined, whilst the protoplasm is unstained, except such fine eosinophil granules as it may contain, which are red; the mononuclears and lymphocytes have sharply defined ruby-red nuclei and faint blue protoplasm; the coarse-grained eosinophiles have a less deeply stained ruby-red nucleus and pale pink granules; the basophiles have dark purple-black granules and ruby-red nucleus; nucleated red cells have almost a black and sharply defined nucleus; the blood-plates are deep ruby-red with spiky margins and sometimes a pale blue peripheral zone. The body of the malarial parasite is stained blue and the chromatin of the nuclei ruby-red; and, in deeply stained preparations of the tertian parasite, the hæmoglobin of the including red blood-corpuscles will be dotted over with certain fine or coarse red granules known as Schüffner's dots.

* When it is not intended to preserve the slides a cover-glass may be dispensed with, and the immersion lens used with only the cedar oil between it and the film. For purposes of diagnosis this suffices, and much time and material are saved. Indeed, stained films retain their colour longest if balsam and cover-glass are not applied.

In preparations intended to display the flagellated body most of the slides will show numbers of spheres and several or many well-stained flagellated bodies (Figs. 3, 4, 7). Very few crescents remain untransformed. If the slips are removed and dried in from five to ten minutes after being placed on the blotting-paper cells, only crescents, ovals, and spheres will be found; if they are left for three-quarters of an hour to an hour, free microgametes and residual masses may also be found, the latter sometimes enclosed in phagocytes. Occasionally, flagellated bodies are found partially included in phagocytes. Staining with carbol-fuchsin, as above described, makes, when successful, beautiful preparations, but they do not differentiate the chromatin of the nuclear elements. To show this, some form of the Romanowsky method, preferably Leishman's or Giemsa's, must be employed.

Cultivation of the Malaria Parasite

The cultivation *in vitro* of the malaria parasite, long and unsuccessfully attempted, was at last (1911) effected by Bass, whose results have been fully confirmed. His method is, briefly, as follows: 10 c.c. of aseptically drawn blood from the median basilic vein of an untreated malaria patient are immediately transferred to a large test-tube containing $\frac{1}{10}$ c.c. of a 50 per cent. solution of Merck's dextrose. The tube is fitted with a cap through which runs a glass rod, and with this the blood is gently defibrinated. The mixture is distributed into culture tubes so as to form columns of about 2 in., and then incubated at 40° C. After a time it settles into three layers—an upper ($\frac{1}{2}$ in.) of serum, an intermediate ($\frac{1}{15}$–$\frac{1}{20}$ in.) of red and white corpuscles, and a bottom of red corpuscles. It is only in the red corpuscles of the very thin intermediate layer that the parasites grow and multiply. They are absent from the serous or top layer, and they die in the bottom layer. By drawing off with a fine pipette a little of the middle layer the progress of the culture can be watched and subcultures started. To succeed with the latter,

however, the leucocytes have to be removed by centrifugation. Strict asepsis and the avoidance of air-bubbles in drawing off and defibrinating the blood are indispensable. The sexual cycle has not been cultivated.

Important results are likely to accrue from Bass's discovery, particularly in the determination of species of parasite, in their morphology, in diagnosis, in the action of quinine, and also in settling disputed points in regard to the latency of malarial infections.

CHAPTER III

MALARIA: DESCRIPTION OF THE PARASITES AND THEIR ASSOCIATED FEVERS

THE different clinical types of malarial disease are associated with different and corresponding species of malaria parasites.

Principles of classification of parasites.—The different species have been classified according to—

1. The duration of their respective life-cycles inside the human body.
2. Their morphological characters.
3. The clinical phenomena they give rise to.
4. The results of inoculation experiments.

It may be said that, so far as these tests go, there is evidence of plurality of species. That is to say, a particular clinical type of malarial disease is associated with a parasite of definite morphological form and intracorporeal life-cycle, characters which are maintained when the parasite has been inoculated experimentally.

In the treatment of this subject the classification suggested by Mannaberg will be followed—a classification based principally on the investigations of Golgi, Marchiafava, Bignami, Celli, Grassi, and other Italians, as well as on his own most excellent work.

The forms of the malaria parasite, and of the diseases they give rise to, may be divided into two comprehensive groups—the *benign* and the *malignant*. A principal morphological distinction between these two groups is that, whereas the benign parasites never form crescent bodies, the malignant parasites, or at least the most important of them—the subtertian—form crescents; that is to say, the gamete of the benign parasites is a sphere or disc, that of the

malignant parasites a crescent. A principal clinical difference between the two is that whereas the benign parasites rarely give rise to pernicious attacks, the malignant parasites frequently do.

The benign parasites are of two kinds: one, the *quartan parasite*, having a cycle of seventy-two hours, causing a fever recurring every three days—*quartan fever*; the other, the *tertian parasite*, with a cycle of forty-eight hours, causing a fever recurring every two days—*tertian fever*.

The malignant parasite has three forms, perhaps more:* a pigmented parasite, the *subtertian*,† of forty-eight, or approximately forty-eight hours' cycle; a pigmented parasite—*pigmented quotidian*—of approximately twenty-four hours' cycle; and an unpigmented parasite—*unpigmented quotidian*—also approximately of twenty-four hours' cycle.

We may arrange them thus:—

Benign	Quartan Tertian	Do not form crescents.
Malignant	Subtertian: Form crescents.	
	Quotidian—pigmented Quotidian—unpigmented	Supposed to form crescents.

Clinical classification.—Formerly, classification being based entirely on clinical phenomena, malarial diseases were divided into quotidian, tertian, and quartan intermittents or agues, and

* Many authorities refuse to recognize more than one species of malignant parasite, the differences in length of cycle and pigmentation described in the text being regarded merely as variations depending on circumstances, and not as specific differences.

† This parasite has received several names, none of them quite appropriate. Thus the Italians call it "æstivo-autumnal," a term appropriate enough in Italy, where the infection is acquired only during the summer and autumn months, but manifestly inappropriate in the tropics, where it may be acquired at any season. Koch calls it the "tropical parasite," a name equally unsuitable, seeing that the range of the parasite embraces countries far beyond the tropic belt. The term subtertian I have adopted, following Sambon's suggestion. It implies no error either as regards clinical habit, seasonal or geographical range, and it has the additional recommendation of approximating to the name hemitertian, applied by Hippocrates and the ancients to the class of fevers it gives rise to.

remittents. But since it has been found that what was designated remittent fever is produced by either quartan, tertian, subtertian, or by quotidian parasites—the fact of intermittency or remittency being more or less a matter of accident—it has been considered advisable to expunge the term remittent fever as indicative of a distinct species of malarial disease. Any one of the five kinds of parasites enumerated may cause what was known as remittent fever. The intermittency or remittency of any given fever depends, in great measure, on the simultaneousness or the reverse of the maturation of the swarm of parasites giving rise to it. If all the parasites present are of nearly the same age, they mature approximately simultaneously and we have an intermittent; if they are of different ages, they mature at different times scattered over the twenty-four hours and we have what was known as a remittent. Further, two generations of tertian parasites maturing on successive days will produce a quotidian fever, *Tertiana duplex;* two generations of quartan parasites maturing on successive days will produce fever fits on two successive days followed by one day of freedom, *Quartana duplex;* three generations of quartan parasites will produce what clinically appears to be a quotidian fever, but in reality is a *Quartana triplex.*

Present classification not final. — The classification adopted must not be accepted as final; at best it is merely provisional. In actual practice it may be hard, often impossible, to bring the cases met with into exact line with such an arrangement. Moreover, as this classification is based in great measure on observations made in very limited districts, principally in Italy, and principally on Roman fevers, it may not apply to the entire malarial world. That it lies on a substratum of fact there can be no doubt; nor can there be much doubt that it has in many particulars a general application to malarial disease as found all over the world. Still, judging from clinical facts, there seems ground for believing that there are other species or

varieties of the malaria parasite besides those described by the Italians, and that the list here given will have to be enlarged or recast in the future. Men with extensive experience of malarial disease in their own persons tell us that they can discriminate by their sensations and symptoms between the fevers of different localities. Analogy would incline us to believe that clinical differences of this sort depend on differences in the determining parasites.

Clinical Phenomena of Malarial Fever

Before proceeding with a description of the various malaria parasites and their associated fevers, there are certain generalities which, to save repetition, had better be mentioned here.

Intermittent fever or ague.—Every typical malarial fever is made up of a series of pyrexial attacks which recur at definite intervals of twenty-four, forty-eight, or seventy-two hours. Each attack consists of a stage of rigor, a stage of heat, and a stage of sweating; these are followed by a period, "the interval," of apyrexia—actual or relative. The duration and intensity of the constituent stages vary considerably. On the whole, they observe a certain proportion to each other; as a rule, the more pronounced the rigor, the higher the fever and the more profuse the sweating. Such attacks, with well-marked intervals of apyrexia, are designated intermittent fevers or agues. The expression "ague" is applied only to intermittents having a pronounced rigor stage.

Premonitory stage.—Before rigor sets in, and sometimes for several days before the actual disease declares itself, there may or there may not be a premonitory stage marked by lassitude, a desire to stretch the limbs and to yawn, aching of the bones, headache, anorexia, perhaps vomiting, perhaps a feeling as of cold water trickling down the back. If the thermometer be used, it will be found that body temperature has begun to rise, it may be some two or three hours before the other and more striking symptoms which ensue set in; or it may be that the threatened attack will subside spontaneously without

culminating in the more pronounced phenomena of a fully developed ague.

Cold stage.—When rigor sets in, the feeling of cold spreads all over the body, becoming so intense that the teeth chatter and the patient shivers and shakes from head to foot. He seeks to cover himself with all the wraps he can lay hands on. Vomiting may become distressing. The features are pinched, the fingers are shrivelled, the skin is blue and cold-looking, and may exhibit the condition known as "goose-skin" (cutis anserina). But the feeling of cold is entirely subjective; if the temperature be taken, it is found to be already several degrees above normal, and to be rapidly mounting. In young children it is not at all unusual to have a convulsive seizure at this stage—a fact that has to be borne in mind, as it is very apt to lead to ideas of epilepsy.

Hot stage.—After a time the shivering gradually abates, giving place to, or alternating with, waves of warmth and, before long, to persisting feelings of intense heat and febrile distress. The wraps, which before were so eagerly hugged, are now tossed off; the face becomes flushed; the pulse is rapid, full, and bounding; headache may be intense; vomiting frequent; respiration hurried; the skin dry and burning; the thermometer mounting to 104°, 105°, 106° F., or even higher.

Sweating stage.—After one or more hours of acute distress the patient breaks out into a profuse perspiration, the sweat literally running off him and saturating his clothes and bedding. With the appearance of diaphoresis the fever rapidly declines; headache, vomiting, thirst, and febrile distress giving place to a feeling of relief and tranquillity. By the time the sweating has ceased the patient may feel quite well; a little languid, perhaps, but able to go about his usual occupation. The bodily temperature is now often subnormal, and may remain so until the approach of the next fit, one, two, or three days later.

Duration of the fit.—The duration of an ague fit and of its constituent stages is very variable. On an average it may be put at six to ten hours, the

cold stage occupying about an hour, the hot stage from three to four hours, the sweating stage from two to four hours.

The urine in ague.—During the cold stage the urine is often limpid and abundant, and is passed frequently; but during the hot and sweating stages it is scanty, loaded, sometimes albuminous. The amount of urea is increased, particularly during the cold stage; and so are the chlorides and sulphates. The phosphates, on the contrary, diminished during the rigor and hot stages, are increased during defervescence. The augmentation in the excretion of urea commences several hours before the subjective symptoms of the attack begin, attains its maximum towards the end of rigor, and decreases during the hot and sweating stages, although still continuing above the normal standard. The excretion of carbonic acid follows a corresponding course. Sydney Ringer was the first to point out the interesting fact that, although the return of fever may be prevented by the administration of quinine, yet, for a time, a periodic increase in the excretion of urea occurs on the days on which the fever fit was due. The urine is often deeply coloured, giving with nitric acid the play of colour characteristic of bile pigment, or the brown colour described by Gübler as "hæmapheic." Glycosuria does occur, but is by no means common.

The spleen during the fit.—The spleen becomes enlarged to a greater or less extent during rigor. At first the swelling disappears in the interval, but it tends to become more or less of a chronic feature if the attacks recur frequently, more especially if they are associated with pronounced cachexia.

Period of the day at which ague commences.—Two-thirds of agues come off between midnight and midday. This is a fact to remember in diagnosis; especially when we have to face the possibility of recurrent pyrexial attacks being dependent on such conditions as liver abscess, tuberculosis, and septic states—conditions, be it remarked, in which febrile recurrence takes place almost invariably during the afternoon or evening.

Atypical agues. — Cases are frequently met with in which all the above symptoms are very much toned down; in which, perhaps, a periodically recurring feeling of coldness, followed by languor, or a slight headache, or a slight rise of temperature, are the only symptoms indicating the presence of the malaria parasite in the blood. In some fevers, and these by no means the least dangerous, the subjective symptoms may at first be of so mild a character that the patient is able to go about his duties with a body temperature of 103° or 104° F.; he may have no severe rigor, no headache, no severe gastric symptoms, no acute febrile distress of a disabling character. Some of the African fevers—so liable to assume suddenly a pernicious character—are of this nature. On the other hand, notwithstanding a comparatively slight rise of temperature, headache, prostration, or vomiting may be extremely distressing. There is an infinite variety in this respect. Evidently the toxin—if toxin there be—of the malaria parasites is far from being a simple body; probably, like tuberculin, it contains several ingredients arranged in different proportions in the several species and varieties of the parasite. Doubtless, also, the degree of infection, various combinations of the species of parasite, and individual idiosyncrasy play a part in determining the intensity and character of the reaction of the human body to the toxin.

Terms employed. — Acute malarial attacks which recur daily are called *quotidian ague;* if they recur every second day, they are called *tertian ague;* if every third day, they are called *quartan ague.* As a rule, the attacks tend to occur about the same time every day. In some cases the time of recurrence becomes earlier each day; such fevers are said to *anticipate.* Or they may occur at a later hour; in which case they are said to *postpone.* When the individual paroxysms are prolonged, so that one attack has not concluded before the next commences, the fever fits are said to be *subintrant.* When the fit is prolonged and periodicity is marked by only a slight fall of temperature, a slight sweating, a

slight feeling of chilliness, the fever is said to *remit*—to be a *remittent*. Sometimes there is no remission; such a fever is said to be *continued*. It occasionally happens that two distinct pyrexial attacks come off the same day; such a fever is said to be *double*. All sorts of blendings of malignant infections, benign tertians, and quartans occur; in such the infection is said to be a *mixed infection*.

Relation of the phenomena of the fever fit to the stages of the parasite. — All the differences and peculiarities in the clinical phenomena of a malarial attack, complicated and hard to interpret in many cases though they be, are, it is believed, directly correlated to the phases of the intracorporeal life of the parasite; this organism is, in fact, the key to their interpretation. As already mentioned, as the time of rigor approaches, the pigment of the parasite, hitherto scattered throughout the substance of the little animal, becomes concentrated, and segmentation proceeds. Shortly before and during rigor, and as a direct cause of rigor, these segmented parasites are breaking up and, presumably, liberating their toxins. At the end of rigor, during the hot and during the sweating stages, the young parasites of the new generation—the small intracorpuscular bodies, and the leucocytes carrying the hæmozoin liberated at the breaking up of the segmented bodies—are in evidence, and the toxins liberated at the same time are being eliminated. During the interval the intracorpuscular parasites grow, become pigmented, and prepare for maturation. From the fact that parasites are present in the blood during apyrexia, and often in great abundance, it is evident that it is not the mere presence of the parasite in the blood corpuscle that causes the fever; most likely, as suggested, the pyrogenic agent is some toxin which is liberated and becomes free in the liquor sanguinis on the breaking up of the parasite. Consequently, we find that in remittent and continued types of malarial fevers segmenting parasites may be met with at all stages of the fever; and, conversely, that when parasites at all stages of development are

met with, the associated fever is probably remittent, irregular, or more or less continued in type.

The foregoing are generalities which apply to all the types of malarial infection.

QUARTAN INFECTION

The parasite.—The parasite of quartan fever, *Plasmodium malariæ* (Fig. 20), has a cycle of seventy-two hours. At its earliest stages of epicorpuscular and of early unpigmented intracorpuscular life it takes the form of a small, roundish, clear speck (Plate I., Fig. 1, *a*), showing up somewhat distinctly against the hæmoglobin of the invaded corpuscle. At this stage, as contrasted with the other species of malaria parasites, it is further

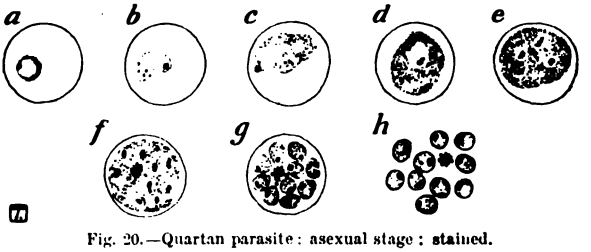
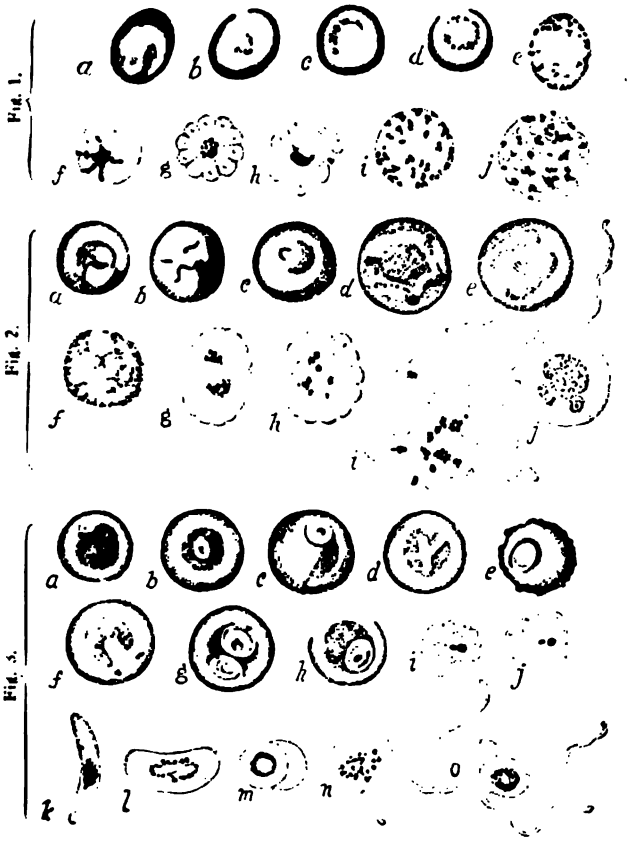


Fig. 20.—Quartan parasite: asexual stage; stained.

distinguished by the feebleness of its amœboid movement. Later, as soon as it becomes pigmented (Fig. 20, *b*, *c*, *d*, *e*, *f*), all amœboid movement ceases. (See also Plate I., Fig. 1, *b*, *c*, *d*, *e*, *f*.) Relatively to the other malaria parasites, the hæmozoin carried by the quartan is large in amount and coarse in grain, sometimes forming short rods. The segmented or mature parasite (Fig. 20, *g*, *h*) is made up of eight to ten elements arranged daisy-fashion and, usually, very symmetrically around the now centrally placed and massive block of very black hæmozoin. About the centre in each of the spherical or pear-shaped segments, which are slightly rough in outline, a shining nucleolus can usually be readily made out.

The gametocyte, or sexual form, is a spherical



Malaria parasites. (*Compiled from Thayer and Hewetson.*)

Fig. 1. Parasite of quartan infection. **Fig. 2.**—Parasite of benign tertian infection. **Fig. 3.** Parasite of subtertian infection ("æstivo-autumnal"). For details of references, see text.

PLATE I

For this reason, and because of the easy visibility of the parasite at all its stages owing to its size and to the large amount of hæmozoin it carries, and because the entire intracorporeal cycle is completed in the peripheral blood, the quartan is the best form of malaria parasite for the beginner to study.

Geographical distribution.—The fever which the quartan parasite gives rise to—single, double, or treble quartan ague—is, relatively, much more common in temperate latitudes than in the tropics. Formerly it was common enough in England; it is still far from rare in the malarious districts of north and mid-Europe and, doubtless, elsewhere under similar climatic and telluric conditions. But, as we proceed south, it becomes, relatively to the other forms of malaria, rarer. In the tropics in some highly malarious places it is unknown. Thus, in a paper read at the Calcutta Medical Congress of 1894, Crombie mentioned that in his large experience he had rarely seen quartan ague. As his experience applied particularly to Calcutta and its environs, it may not hold for the whole country; in fact, Ross and others state that the quartan parasite is common enough in Madras and elsewhere in India. It is the dominating species in certain malarious districts of Ceylon and the Malay States. I have seen it in blood films from Mauritius; Ross mentions it as occurring in Sierra Leone. Doubtless it occurs in limited districts throughout the tropics. Thus, though relatively rare in many of the West India Islands, it is a common form, according to Freeman, in Antigua. The general statements that quartan ague is, relatively to the other forms of malaria, more a disease of the temperate zones than of the tropics, and, further, that both in the tropical and temperate zones it has topographically a very limited distribution, probably express the truth.

The fever.—The ague fit in quartan is generally smart while it lasts, and well defined as regards its constituent stages (Chart 1). It does not tend so markedly, as is the case with the other malarial infections, to the rapid development of cachexia.

Although the individual attacks are very amenable to quinine, the infection appears to be of a more persistent nature than that of tertian and subtertian malaria; attacks, therefore, are prone to recur during several years.

Tertian Infection

The parasite.—The early stage of the benign tertian parasite, *Plasmodium vivax* (Plate I., Fig. 2),

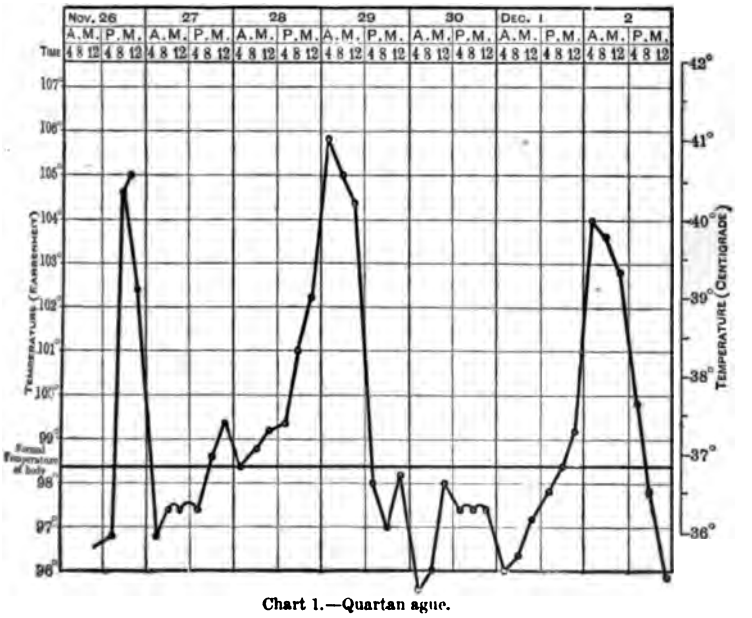


Chart 1.—Quartan ague.

resembles that of the quartan inasmuch as it consists of a small pale speck on, or in, the invaded red blood-corpuscle (Plate I., Fig. 2, *a*); it differs in exhibiting very much greater amœboid activity, changing its form and location in the corpuscle incessantly, besides pushing out and retracting pseudopodia (Plate I., Fig. 2, *b*). This amœboid activity persists during growth and the formation of hæmozoin, though in a progressively diminishing degree; it gives rise to great and rapidly

changing irregularities in the contour of the parasite (Plate I., Fig. 2, *c*, *d*, *e*), but is almost entirely suspended by the time hæmozoin-concentration is effected. In the tertian parasite the hæmozoin particles are, on the whole, finer than those of the quartan parasite; and, moreover, are in a state of much more active and incessant movement, constantly changing their position in the peripheral region in which they, for the most part, seem to lie (Plate I., Fig. 2, *f*). Another, and highly characteristic, accompaniment of tertian infection is the considerable hypertrophy and marked decoloration of the corpuscles containing the parasite (Plate I., Fig. 2, *d*, *e*, *f*, *g*). Sometimes the affected corpuscles seem nearly twice the diameter of the healthy ones; and nearly always, if the parasite is of any magnitude, the rim of hæmoglobin has a "washed-out" look, sometimes being almost colourless.

In corpuscles invaded by the tertian parasite, deep coloration with Leishman's or Giemsa's stains brings out a feature which does not occur in those attacked by quartan or subtertian parasites. With these stains in tertian-invaded corpuscles the hæmoglobin is speckled with chromophilic particles called "Schüffner's dots." This is a feature of some diagnostic value. In the very young phases of the parasite it is not always present; unfortunately for its diagnostic value, these are just the phases that are difficult to diagnose from quartans and subtertians.

In the tertian parasite, when segmentation is completed, the resulting body, instead of the very symmetrical, daisy-like figure of the quartan, resembles rather a cluster of grapes in some more or less central part of which one or two masses of dark pigment have accumulated among the berries (Plate I., Fig. 2, *h*; also Figs. 1 and 2, *b*). The little spherules forming the cluster—fifteen to twenty-six in number—are smaller, smoother, and more spherical than those of the quartan parasite; seldom, in the unstained condition, exhibiting their nuclei. I believe that in natural, uncompressed conditions the tertian "rosette," as it is called, tends to pass from the disc form,

impressed on it originally by the shape of the corpuscle, to something more approaching a globular form.

In the tertian, as in the quartan parasite, the gametocyte is a spherical body resembling closely the mature parasite from which the segmented body is evolved (Plate I., Fig. 2, *j*). It is seen more particularly, just as in the case of the quartan infection, after and not infrequently about the time of rigor. The tertian gametocyte is considerably larger than that of the quartan and subtertian parasite.

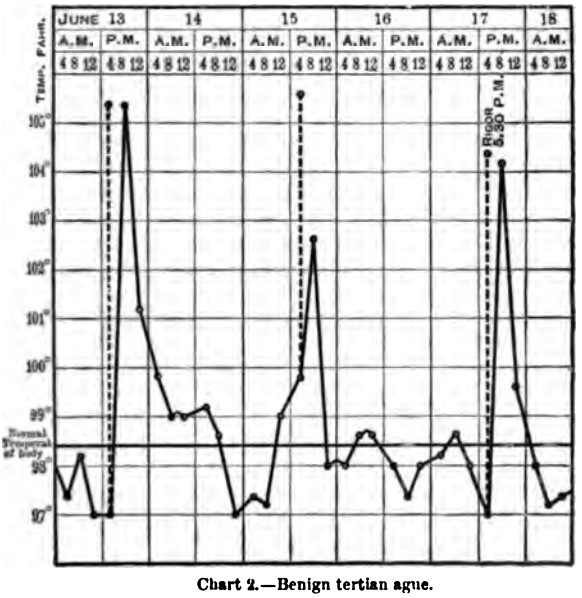


Chart 2.—Benign tertian ague.

Geographical distribution.—The tertian parasite, probably the commonest form of malaria parasite, occurs in temperate and tropical latitudes alike. It is often met with as a double infection, and is, perhaps, the most frequent cause of quotidian as well as of tertian agues.

The fever.—The fever it gives rise to, except in the matter of the spacing, which is one of forty-eight

hours, resembles that caused by the quartan parasite (Chart 2).

Malignant Infections

Many authorities refuse to recognize more than one species of crescent-forming parasite. On the other hand, carefully conducted observations, both microscopical and clinical, seem to indicate a plurality of species. I shall follow the latter view.

The three parasites (Plate I., Fig. 3, and Plate II., Fig. 1) described by the Italian pathologists in connection with malignant malarial infection, although often associated together as well as with the benign parasites, are each of them occasionally found in what may be termed pure culture. From a study of such cases the morphological and distinguishing characters of the different species, and their special pathological effects, have been more or less satisfactorily made out. Although much remains to be done, enough is already known to enable us, in a measure, to differentiate them from each other as well as from the benign parasites, and to justify their being placed in a group by themselves.

Characters possessed in common by the malignant parasites. — One notable feature in regard to them is that they are very much smaller than the benign parasites. The earlier unpigmented phase, owing partly to minuteness, partly to its forming but a thin and very transparent object in the hæmoglobin, is hard to see. When first mounted on the slide the amœboid movements are very active (Plate I., Fig. 3, *d*). In a short time these subside somewhat, and then the little parasites tend to assume a more passive condition and to arrange themselves as tiny, though very definite and easily recognized, rather bright, colourless rings (Plate I., Fig. 3, *a*, *b*, *c*, *e*). Sometimes these rings may revert to the amœboid condition, and this, perhaps, for several times in succession; ultimately the ring form becomes permanent. Multiple infection of individual corpuscles (Plate I., Fig. 3, *g*) is often encountered, and this much more frequently than in the benign infections; doubtless, this is owing to the

FIG. 1.

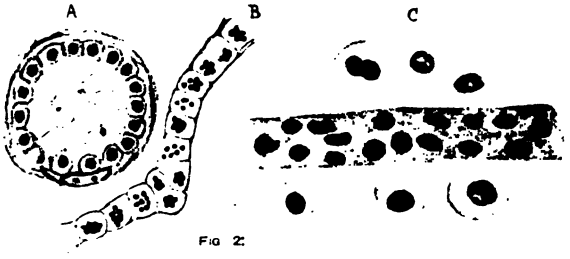


FIG 2.

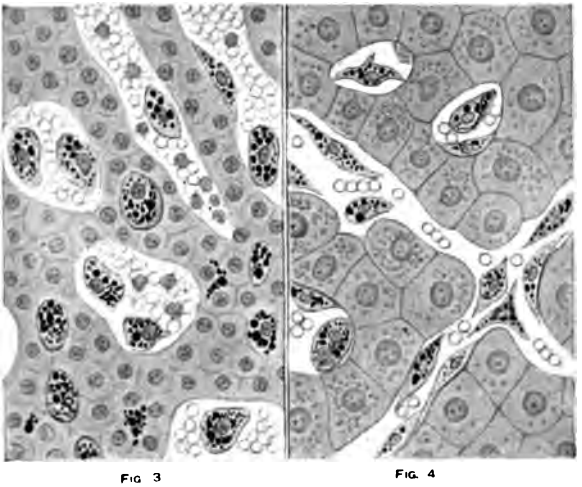


FIG 3 FIG. 4

Malaria parasites. (*Kelsch and Kiener.*)

Fig. 1. Parasites of the pigmented malignant quotidian (*Marchiafava and Bignami*). **Fig. 2.**—Brain capillaries containing malaria parasites. A, transverse section, the blood-corpuscles at periphery invaded by unpigmented parasites; B, vessel filled with sporulating unpigmented parasites; C, blood-corpuscles in capillary, and others free in the brain substance, each containing small pigmented parasites (*Mannaberg*). **Fig. 3.** Pernicious malaria (spleen). **Fig. 4.** Pernicious malaria (liver).

PLATE II.

prodigious number of parasites present in some malignant infections. As development advances, the invaded corpuscles seem to be filtered out by the capillaries and small arteries (Plate II., Fig. 2, A, B, C) of the deeper viscera and of the bone marrow. So that even in severe infections the later pigmented stages are by no means proportionately represented by, or even frequently encountered in, finger blood; the segmenting form (Plate I., Fig. 3, *i*, *j*) still less so. To find numerous examples of the more advanced stages of these parasites it is necessary to aspirate splenic blood, or to search in fatal cases in the deeper viscera, or in the bone marrow immediately after death. Owing to this absence of the more advanced forms from the peripheral circulation, the duration of the life-span of these parasites is difficult to fix; probably it varies between twenty-four and forty-eight hours, being not very constant even in the same type.

"Brassy bodies."—Malignant parasites frequently lead to a shrivelling of the invaded corpuscles many of which, in consequence, are small, crenated, or folded, and very dark. This corpuscle the Italians, from its colour, have designated "brassy body" (Plate I., Fig. 3, *e*). In the interior of these corpuscles the parasite can generally be made out as a minute pale ring.

The crescent body characteristic.—Most distinctive feature of all, the malignant parasites—at all events the subtertian—form crescent gametocytes.

Time when crescents appear; not a fever form.—It has been already remarked that these crescent bodies are not to be seen at the very commencement of an infection. A week usually elapses between the first appearance in the peripheral blood of the small intracorpuscular parasites and the first appearance of the crescent bodies.* Once the latter begin to appear

* There has been a good deal of speculation as to why certain parasites develop into schizonts, whilst others become gametocytes. The circumstance of the late appearance of the gamete is looked upon by some as evidence that the blood, from repeated development in it of swarms of endogenous parasites, has become exhausted as a pabulum, and that in consequence of this the parasite is directed to a line of development providing for life and growth elsewhere, that is in the mosquito. The analogy of other sporozoa and of the bacteria supports this view.

they generally tend to increase in number during a few days. They may persist, though after a time in decreasing numbers, in the circulation for one, two, three, or even six weeks after the small fever-causing intracorpuscular parasites and their associated fever have disappeared, whether spontaneously or in consequence of the administration of quinine. Although, when given early in an infection, quinine may prevent the appearance of crescents, yet, when they are once formed, the drug has apparently no influence on these bodies nor on their capacity for emitting microgametes. The crescent body does not cause fever; its presence is usually associated with marked cachexia.

It is a singular fact that in many of the worst types of tropical malaria—as that of tropical Africa—crescents are few in number, and in some instances cannot by ordinary examination be found. A. Plehn states that during a period of two years in Africa he only once saw the flagellated body. On the other hand, when we meet with these African infections in England, crescents are frequently encountered, and often in great abundance; at all events, this is my experience.

Characters of the fever.—It is found that the fevers produced by the malignant parasites are apt to be very irregular in their course. The rigor stage is relatively less marked; the pyrexial stage is more drolonged, and is often characterized by a tendency to adynamic conditions, together with vomiting, intestinal catarrh, pains in the limbs, anorexia, severe headache, and depression. After apparent recovery from the fever there is a great proneness to relapse at more or less definite intervals of from eight to fourteen days. Such fevers are accompanied by rapid destruction of corpuscles, and are usually followed by marked cachexia. At any time in their course symptoms of the gravest character may declare themselves.

Quotidian Infections

The quotidian infections are comparatively rare; at all events, they have not been very frequently

recognized or adequately described. Many regard them as but varieties of the common subtertian infection.

The parasite.—The parasites are said to be of two kinds (very generally in association), the pigmented, *Laverania præcox* (Plate II., Fig. 1), and the unpigmented, *Laverania immaculata*. In both the cycle is approximately one of twenty-four hours; in both the young parasites exhibit very active movements, and tend to assume the ring form. Before segmentation they grow so as to occupy from one-fifth

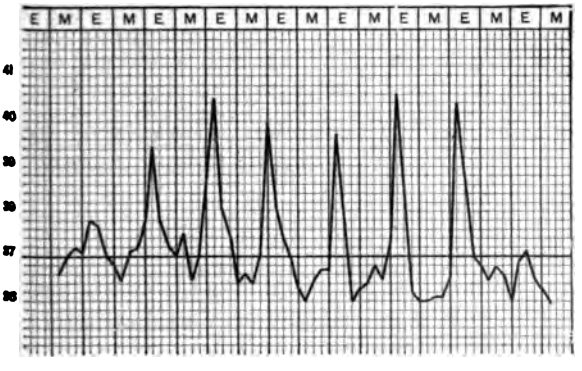


Chart 3.—Quotidian infection.

to one-third only of the corpuscle. Both form little heaps of from six to eight very minute spores.

In the unpigmented parasite hæmozoin is never seen unless it be in the crescent phase—a phase the occurrence of which has not been satisfactorily established; in this phase, however, hæmozoin is never absent. In the pigmented parasite there is a considerable amount of fine hæmozoin, which at the segmenting stage—rarely seen in peripheral blood—collects in the usual way into one or two more or less central clumps.

The fever.—The fever is such as just described, a typhoid-like depression being generally a prominent feature in well-marked cases (Chart 3).

SUBTERTIAN INFECTION

The parasite.—*Laverania malariæ* (*Plasmodium falciparum*, Blan.)—the usual parasite (Fig. 21) of malignant infection—is, in many respects, like that of ordinary tertian, only smaller, attaining when mature from a half to two-thirds the size of the corpuscle it occupies. The infected blood-corpuscle may be altered in colour in the direction of being either darker or lighter; sometimes it shrinks, or it may become a "brassy body." The segments of the rarely encountered mature segmenting parasite number usually ten or twelve, and are arranged along with the associated clump or clumps of hæmo-

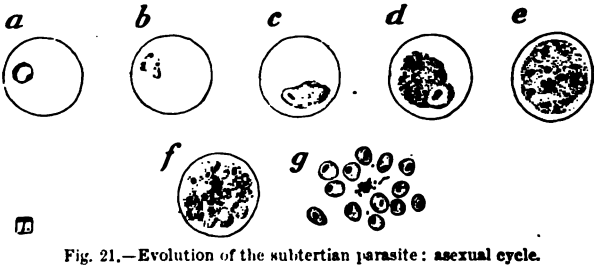


Fig. 21.—Evolution of the subtertian parasite: asexual cycle.

zoin in an irregular heap. The crescent-shaped gametocyte is a characteristic feature.

The fever.—The associated symptoms are, in many respects, very different from those caused by the tertian parasite. In the first place, though rigor is not so marked, the hot stage lasts longer—often exceeding twenty-four hours; in fact, the tendency for the successive paroxysms to overlap, to become subintrant, is very marked. Moreover, where the intermissions are distinct, as Marchiafava and Bignami point out, the crisis is generally unlike that of ordinary tertian. There is frequently what is called a "double crisis"; that is to say, when the fever has attained its apparent fastigium there is a drop of one or more degrees of temperature—the "false crisis"—to be followed by a fresh rise, which is then followed

by the "true crisis." This peculiar phenomenon the writers referred to attribute to the presence of two swarms of parasites, one of which matures somewhat later than the other. (Chart 4.)

The tendency to the development of pernicious symptoms, to the production of cachexia, and to relapse is similar to what appears to be the case in malignant quotidian infections.

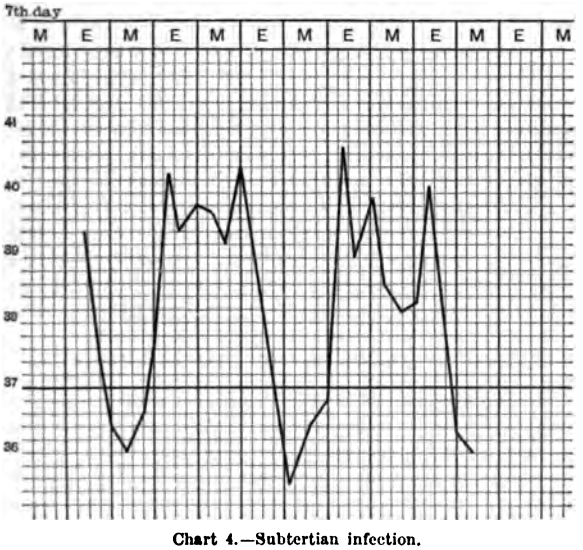


Chart 4.—Subtertian infection.

Geographical distribution.—All these malignant parasites are confined to the warmer regions of the earth, and to the more intensely malarial districts in these; hence the name "tropical" which has been applied to this type of infection. In the sub-tropical zones they occur as first infections only in late summer or early autumn; hence the name "æstivo-autumnal."*

* This peculiarity as regards seasonal and geographical distribution of subtertian malaria may be explained, as Grassi, Jancsó, and others have pointed out, by the fact that for its development in the mosquito the subtertian parasite demands a higher

Microscopical examinations in malignant fevers.—In malignant infections the pigmented phase of the fever-causing forms of the parasite is not very frequently met with in peripheral blood. When found, and especially when it is observed that the pigment has become concentrated, it is a sure indication that a paroxysm is impending. On the occurrence of chilliness or of rigor, and at least during the earlier stages of the paroxysm, many small unpigmented parasites, sometimes exhibiting active amœboid movement, sometimes appearing as rings, will be found in finger blood; but towards the end of the fever these unpigmented forms often diminish in number, and all evidence of parasitic infection may even disappear from the blood till the approach or incidence of the next paroxysm. Of course, crescents and pigmented leucocytes may be found during these temporary absences of the intracorpuscular parasites. The segmenting forms of the malignant parasite are best found by aspirating the spleen with a hypodermic needle—hardly a justifiable procedure unless in exceptional circumstances.

Clinical Forms of Malarial Fevers

General statements.—The foregoing account, so far as it goes, and so far as it relates to the clinical manifestations produced by uncomplicated and typical infections, is true enough. But, as there may be an infinite variety as regards the number of the parasites present, individual susceptibility, concurrence of several species (mixed infection being far from uncommon), or of several generations of the same species of parasite maturing at different times, there may be a corresponding variety in the clinical manifestations.

In more temperate climates, and in the winter and spring seasons of warmer latitudes, malarial

atmospheric temperature than suffices for the quartan and tertian parasites. Hence, although these two benign and the subtertian parasites are generally found associated together, and the latter can be acquired at any time in the tropics, it is only in the summer or early autumn that it can be acquired in the sub-tropics and temperate zones. It is stated that if the temperature falls below 15° C. the development of the oöcyst in the mosquito is arrested.

fevers are usually distinct intermittents. Fresh infections occurring in these places and seasons, so far as the subject has been studied, are found to be produced by the tertian and quartan parasites, and are, therefore, of little danger. Relapses, however, of malignant infections, originally contracted during the hot weather, may occur during the cold season—in fact, are far from uncommon then.

First attacks, though produced by one of the benign parasites, may assume the characters of a remittent; generally, in temperate latitudes, they are frank intermittents. First attacks of malignant malaria, although they may in a few instances be intermittent, are in the majority of cases remittent in type. So are the attacks resulting from extensive reinforcement by fresh parasites (through fresh infection) of the old stock which a fever subject may carry about him in a latent condition. The first attack experienced by a new-comer to a highly malarious district with a hot climate is, therefore, generally remittent and severe.

It is neither necessary nor desirable to attempt to describe in detail the infinite variety malarial attacks exhibit. It would be impossible in a limited space to do so; and, if done, the result would amount only to an uninteresting and unprofitable ringing of the changes on rigor, pyrexia, diaphoresis, bilious vomiting, bilious diarrhœa, constipation, catarrhal gastritis, headache, bone-ache, prostration, and so forth. The picture would be further confused by the fact that the natural procession of events is generally, nowadays, disturbed by the action of quinine, the use of which is almost universal with Europeans in the tropics; so that it is difficult to say how any given malarial fever would develop, or how it would terminate, if untreated. Sometimes in the case of natives of tropical countries, who may not always command a few grains of quinine, such fevers pass into a typhoid state, with dry brown tongue, sordes in the mouth, and muttering delirium, and may end in collapse and death. In others, untreated remittents and intermittents gradually subside spontaneously in the course of a week or fortnight; or

the remittent may merge into an intermittent which, in the course of weeks or months, subsides for a time, to recur every now and again at longer or shorter intervals. These recurrences may take place at fairly definite intervals; "long-interval fevers" the Italians have named them. Kelsch and Kiener allowed certain remittents in Europeans to run their course unchecked by quinine; they found that in ten or twelve days the fever gradually expended itself. Under favourable hygienic conditions the parasite and the associated fever frequently disappear together spontaneously. Occasionally the fever forms of the parasite may be present in the blood for days on end without causing acute clinical symptoms.

Remittent Types

Bilious remittent.—One type of fever, known as bilious remittent, has long been recognized on account of the bilious vomiting, gastric distress, sometimes bilious diarrhœa, sometimes constipation, which accompany the recurring exacerbations. It is further distinguished by the pronounced icteric or, rather, reddish-yellow or saffron tint of skin and scleræ; a tint derived, probably, not from absorption of bile as in obstructive jaundice, but from modified hæmoglobin (hæmaphein) free in the blood or deposited in the derma and sclerotica. These bilious remittents are very common in the more highly malarious districts of Africa, America, the West Indies, India, and, in fact, in all malarious tropical countries. They are not specially nor directly dangerous in themselves, but they result usually in profound anæmia, and are often but the prelude to chronic malarial saturation, bad health, and invaliding.

Typhoid remittent.—A modification of the bilious remittent—what Kelsch and Kiener call "typhoid remittent"—is very much more grave as affecting life than the simple bilious remittent. In the typhoid remittent, typhoid symptoms—such as low delirium, prostration, dry tongue, swelling of spleen and liver, subsultus tendinum, marked melanæmia—are superadded to the usual symptoms. Though re-

covery is the rule, a considerable proportion of such attacks prove fatal.

Adynamic remittent.—The same writers class by themselves a set of cases they call "adynamic remittent"; cases which are characterized by fatuousness, restlessness, nervous depression, intense muscular and cardiac debility, profound and rapid blood deterioration, icterus, leucocytosis, melanæmia, liability to syncope, occasionally hæmoglobinuria, liability to hæmorrhages, and a marked tendency to local gangrene.

Tuberculosis, syphilis, renal disease, or alcoholism will often be found as factors in determining the two latter types of fever.

Pernicious Attacks

Many writers have drawn attention to what are called pernicious attacks or pernicious symptoms—the French neatly designate them "accès pernicieux"—a series of phenomena, the possibility of the appearance of which, not only in the course of remittents, but in the course of what is seemingly only an ordinary paroxysm of intermittent fever, should never be lost sight of by the practitioner in tropical climates. These "accès pernicieux" may supervene in apparently mild cases and carry off the patient with horrifying suddenness—as suddenly as an attack of malignant cholera. The wary practitioner is always on the look-out for them, and is always prepared with measures to meet them promptly when they threaten.

Pernicious attacks are roughly classified into cerebral and algide. The cerebral are divisible into hyperpyrexial, comatose, convulsive, paretic, and so forth; the algide into syncopal, choleriform, dysenteric, hæmorrhagic, etc.

Cerebral Forms

Hyperpyrexial.—There can be little doubt that many of the cases of sudden death from hyperpyrexia and coma, usually credited to what has been called "ardent fever" or "heat apoplexy," are really malarial. If careful inquiry be made into the

antecedents of many of these cases, a history of mild intermittent fever will often be elicited; or it will be found that the patient had been living in some highly malarious locality.

In the course of what seemed to be an ordinary malarial attack the body temperature, instead of stopping at 104° or 105° F., may continue to rise and, passing 107°, rapidly mount to 110° or even to 112°. The patient, after a brief stage of wild maniacal or, perhaps, muttering delirium, becomes rapidly unconscious, then comatose, and dies within a few hours, or perhaps within an hour, of the onset of the pernicious symptoms.

Comatose.—Or the patient, without hyperpyrexia, the thermometer perhaps not rising above 104°, or even lower, may lapse into coma. The coma may pass away with crisis of sweating; on the other hand, an asthenic condition may set in and death from collapse supervene.

Other cerebral forms.—Besides these hyperpyretic and comatose conditions, other forms of cerebral attack may occur in the course of malarial fevers. Thus, there may be *sudden delirium* ending in coma and, perhaps, death: *convulsive seizures* of an epileptic or of a tetanic character, with or without delirium or coma—forms especially common in children, and too often misdiagnosed and with fatal consequences; conditions simulating *cerebro-spinal meningitis; delusional insanity; dementia;* various forms of *apoplectic*-like conditions and of *paralysis*, complicated, it may be, with *aphasia*. Seizures of this description, if not fatal, may eventuate in *permanent psychical disturbances*. Temporary debility, or even complete *loss of memory*, may succeed severe malarial infection.

Embolism of cerebral capillaries.—These cerebral attacks are now explained, and it appears to me correctly explained, by the supposition, founded on actual post-mortem observation, that they depend on embolism by the malaria parasite of the capillaries of the various nerve centres involved (Plate II., Fig. 2); in hyperpyrexia, the thermic centres; in

aphasia, Broca's convolution ; and so on. By microscopical examination of properly prepared sections of the brain in fatal cases, such a plugging of the vessels can generally be readily observed. The earlier students of malarial melanæmia had remarked the presence of hæmozoin in the cerebral capillaries in many cases of this description, and, overlooking the including parasite, attributed the associated symptoms to thrombosis by the hæmozoin.

Malarial amblyopia.—In rare instances a comatose pernicious attack eventuates in blindness. The amblyopia is usually transient, lasting for an hour or two only. On the other hand, it may be persistent; in which case, according to Poncet, optic neuritis, peripapillary œdema, extravasation of leucocytes, plugging of retinal and choroidal vessels by parasites or pigmented leucocytes, and consequent multiple hæmorrhages, may be found in the fundus. If the hæmorrhages are minute they are discoverable by the microscope only. These fundus changes differ from those in quinine amblyopia. In the latter, depending on retinal anæmia from toxic spasm of the arterioles, the amblyopia is more persistent ; the discs are white and the vessels shrunken ; there are no inflammatory symptoms; and central vision is the first to recover. (*See* Table on p. 76.)

ALGIDE FORMS

The algide forms of pernicious attack, as indicated by the name, are characterized by collapse, extreme coldness of the surface of the body, and a tendency to fatal syncope. These symptoms usually coexist with elevated axillary and rectal temperature.

Gastric form.—This may be associated with, and in a measure be dependent on, acute catarrhal dyspeptic trouble. It is accompanied by severe epigastric distress, tender retracted abdomen, and incessant vomiting. The vomited matter may contain blood.

Choleraic form.—Malarial attacks are sometimes accompanied by choleraic symptoms. The stools suddenly become loose, profuse, and numerous. They

TABLE OF DIAGNOSTIC POINTS IN QUININE AND MALARIAL AMBLYOPIA (*see* p. 75)

QUININE AMBLYOPIA	MALARIAL AMBLYOPIA
History.—Quinine taken in large doses, not less than 30 grains.	*History.*—Quinine may have been taken, but not necessarily in large doses.
Onset.—Sudden, accompanied by deafness; both eyes are affected.	*Onset.*—Not usually sudden, but it may be so if hæmorrhage has occurred in the macular region. There is no deafness, and both eyes are not necessarily affected.
Pupils.—Widely dilated, and whilst loss of vision continues they do not react to light.	*Pupils.*—React to light.
Vision.—Completely lost for a time.	*Vision.*—Never completely lost.
Ophthalmoscopic appearances.—A white haze over fundus; cherry-red spot at macula; optic disc pale; retinal vessels markedly constricted.	*Ophthalmoscopic appearances.*—There is optic neuritis; optic disc is of characteristic greyish-red colour; retinal hæmorrhages, and sometimes vitreous opacities.
Termination.—Usually some permanent defect in the field of vision or in colour vision. Central vision recovers first; optic disc is unusually white, and retinal vessels small.	*Termination.*—Some cases recover completely; in others greater or less permanent defect of vision remains.
Treatment.—Stop quinine. Amyl nitrite has been recommended to induce dilatation of retinal vessels.	*Treatment.*—Give quinine.

are not generally so profuse or colourless as the rice-water discharge which pours from the patient in true cholera; they retain a certain amount of biliary colouring, and may be mucoid or even bloody. As in cholera, the serous drain may lead to cramps in the limbs, loss of voice, pinched features, "washer-woman's fingers," almost complete suppression of urine, and, perhaps, to fatal collapse. Such attacks are very deceptive, and may be mistaken for true cholera. The high axillary temperature, if present; a history, maybe, of recent ague fits; the subsequent rapid disappearance of choleraic symptoms on the appearance of the hot and sweating stages; the colour of the stools, and other collateral circumstances, usually suffice for diagnosis, particularly if they are supplemented by a microscopical examination of the blood. Although not usual, recurrence of the choleraic symptoms may take place at the next fever period. A dangerous type of malarial fever prevalent in the Punjab is often ushered in by such symptoms; without the microscope its true nature may be hard to recognize.

Dysenteric and hæmorrhagic forms.—Another form of pernicious attack is characterized by the sudden appearance of dysenteric symptoms; yet another by severe and recurring hæmatemesis, or by hæmorrhage from the bowel or elsewhere. The possibility of a suddenly developed dysentery being of malarial origin must therefore be kept in view; particularly if in what appears to be ordinary dysentery axillary temperature is found to be abnormally high. In every case of dysentery of this kind, or of hæmorrhage from stomach or bowel, in a patient who has recently been exposed to the chance of malarial infection, the possibility of the symptoms being an expression of malarial disease must never be overlooked; an examination of the blood must be made in all such cases before treatment is instituted.

Syncopal form.—In the preceding types of algide pernicious malarial attack the dangerous symptoms mostly show themselves in the rigor stage of the fever. There is yet another form in which the danger

appears to depend on an exaggeration of the symptom usually hailed as bringing relief and, for the time, freedom from danger. Thus the sweating of the stage of defervescence may be excessive and cause collapse, which, if the patient rise up suddenly or make an undue effort, may lead to fatal syncope. Weak and cachectic patients, therefore, should be warned of this possibility.

The **pathology** of these various forms of algidity is in all likelihood of a very mixed character. In the gastric, choleraic, hæmorrhagic, and dysenteric types there is probably an accumulation of parasites in the vessels of the intestinal mucosa; such accumulations of parasites have been described. In those attacks in which profuse sweating is the dangerous element, the diaphoresis may be regarded, at all events in part, as symptomatic of excessive blood destruction—of what is, in reality, equivalent to a sudden and extensive hæmorrhage; or it may be that it is only an excessive reaction to the malarial toxin. The dangerous syncope attending all types of algidity is secondary, and merely an expression of collapse.

A phenomenon occasionally observed in pernicious attacks, especially in those of an algide type, is the flooding of the peripheral blood with vast numbers of parasites, it may be at all stages of development—gametes as well as schizonts. The prognosis in such cases is bad.

A practical experience of these suddenly developed pernicious fevers of the tropics teaches that we should never make light of any malarial attack; particularly if it be of a mild irregular character and imperfectly controlled by quinine, and if small parasites, or the crescent form, be present. The practitioner should be on the alert for any danger signal—mental aberration, restlessness, tremor, peculiarity in behaviour, alteration in knee reflexes, and other indications of grave implication of the nervous system. It further teaches that the subjects of such fevers should be particularly careful to guard against chills, fatigue, insufficient and unwholesome food, etc.

CHAPTER IV

MALARIA: MORBID ANATOMY AND PATHOLOGY

The blood in malaria.—As the malaria parasite is a blood parasite, we naturally expect that the primary effect of its presence will be exercised on, and manifested in, the blood; and as the parasite lives in and at the expense of the corpuscles, destroying a certain proportion of them—in fact, all those attacked—we look, in the first instance, for a corresponding diminution in the number of the corpuscles—an oligocythæmia.

Oligocythæmia.—Accordingly, when in malarial disease we come to measure accurately the corpuscular richness of the blood, we do find a decided oligocythæmia. And not only this, but we find a degree of oligocythæmia greatly in excess of anything we might expect; or which can be accounted for by, or is in correspondence with, the proportion of corpuscles attacked and directly consumed by the parasite, judging by what we see in finger blood—peripheral blood. If, for example, every hundredth corpuscle contains a parasite we might look for something like a quotidian, tertian, or quartan 1 per cent. reduction in the total number of blood corpuscles; if every twentieth corpuscle contains a parasite—a very high and unusual proportion—we might look for a similarly-timed 5 per cent. reduction.

Now, this is an amount of hæmolysis which should be easily compensated by the latent physiological hæmogenic margin, and which one would not expect to show as a definite anæmia, or would expect to show only after the recurring drain had been kept up for some considerable time. But what are the clinical facts? One or two paroxysms only, of some malarial fevers, may be immediately followed by an

anæmia so pronounced as to be discernible to the eye in the intense pallor of the skin and visible mucous surfaces. On counting the corpuscles in such a case we note a regular drop in their number of from 5 to 10 per cent. per paroxysm. Often, after a single paroxysm of some pernicious fever, as many as half a million, or even one million corpuscles per c.mm. drop out of the normal five millions; and this reduction may go on, as paroxysm follows paroxysm, until the corpuscular richness has fallen to one million, or even less.

Diminished hæmoglobin value of corpuscles.—Not only is there in many, in fact in most, cases of malarial disease a pronounced oligocythæmia, but there is, in addition, a marked diminution in the hæmoglobin value of the surviving corpuscles; it may fall 10, 20, or even as much as 50 per cent.

Diminished amount of blood.—And not only is there this marked diminution in the proportion of the corpuscles to the bulk of the blood and in their hæmoglobin value, but there is, furthermore, in all malarial conditions of any considerable standing a marked diminution in the volume of blood. Thus it comes that at the post-mortem examination of such a case we do not always meet with that congestion of the organs which is so usual a feature in most specific fevers. On the contrary, although in quite recent cases visceral congestion may be marked enough, if a malarial fever has been of any considerable duration the venous system, with the exception of that appertaining to the spleen, liver, and portal system generally, may be markedly empty. And thus it is that often, when we would make a preparation of blood from the living malarial patient, we may find that not only is the blood thin and watery, but that it does not flow freely from the pricked finger.

Destruction and reparation of blood in first attacks and in relapses.—There appears to be no very definite or manifest law governing the degree, progress, and quality of the anæmia of malarial disease. On the whole, and as rough general rules, it may be laid down that in any given case the anæmia is in pro-

portion to the severity of the febrile attacks; that, although the loss of corpuscles following first attacks is usually very marked, this loss is rapidly made good; that, although in relapses the loss of corpuscles is less than in first attacks, the tendency to reparation is also less.

Morbid anatomy: *Macroscopic.*—If the body of a patient who has died in the course of an acute attack of malarial disease be dissected, certain appearances are generally found. In the first place, and invariably, the *spleen* is enlarged—often very much enlarged; its surface is dark—black sometimes—what is called pigmented. On section, the gland tissue is also found to be dark. Generally the parenchyma of the organ is so much softened as to be almost diffluent, so that the tarry pulp can sometimes be washed away by quite a gentle stream of water. The *liver*, too, is softened, congested, enlarged, and pigmented. The vessels of the *pia mater* and *brain cortex* are full, and the grey matter may present a peculiar leaden hue. The *marrow* of the spongy bones, such as the sternum and the bodies of the vertebræ, is also dark and congested; and a similar state of pigmentation and perhaps congestion may be discovered in the *lungs, alimentary canal*, and *kidneys*.

Microscopic: Malarial pigmentation.—The pigmentation referred to is pathognomonic of malaria. On submitting malarial blood from any part of the body to microscopical examination, it will be found to contain grains of hæmozoin. Particularly is this the case with blood from the organs just mentioned; microscopic sections (Plate II., Figs. 2, 3, 4) will show more or less thickly distributed in the blood, and within the cells of the endothelium of the arterioles and capillaries, minute grains, or actual blocks, of the same intensely black substance. For the most part the hæmozoin grains are enclosed in leucocyte-like bodies which are either clinging to the walls or lying loose in the lumen of the vessels. Here and there the pigmented bodies may be so aggregated together that they form veritable thrombi and occlude the vessels. It is possible that many of

these bodies are not pigmented leucocytes, but are really dead and breaking-down parasites; for if the preparations were made within two or three hours of death—that is to say, when the tissues were quite fresh—it may be possible to see that the capillaries of some of the organs are full not only of hæmozoin but also of parasites, a very large proportion of the blood corpuscles containing them. Particularly is this the case with the spleen and bone marrow; often, too, with the brain, liver, epiploön, and intestinal mucosa. The spleen and bone marrow are further distinguished from the other organs mentioned by the position in which the hæmozoin occurs in them. In all organs the pigment is found in the blood-vessels, but only in these two organs is it found in the cells of the parenchyma as well, and outside and away from the blood-vessels. This extravascular pigment is either free, or it lies in the large cells characteristic of these organs, or in the small cells of the parenchyma.

Nature and source of malarial pigment.—In colour, in structure, and in chemical reaction this pigment corresponds exactly with the pigment already described as forming so prominent a feature in the malaria parasites themselves. Like this, it is insoluble even in strong acids; it is altered by potash, and is entirely and rapidly dissolved by ammonium sulphide. In recent infections it occurs as minute dust-like grains; in infections of some standing as coarser particles, or as agglomerations of these into irregular, mammillated lumps. So far as the circulation is concerned, such a pigment is found in no other disease whatever. As an extravascular pathological product a similar pigment is found in certain melanotic tumours; but only in the cells of the tumour, never in the blood-vessels. Pigments of several kinds are found in old blood-clots; but such pigments are manifestly different from that of malaria, and yield very different chemical reactions. Intravascular black pigment, therefore, is absolutely pathognomonic of malaria.* Because of

* The pigment-like dot occurring in a large proportion of the lymphocytes in normal blood (*see* p. 38) must not be confounded with malarial pigment.

its physical characters, and of the circumstances in which it occurs, hæmozoin may with confidence be regarded as the specific product of the malaria parasite itself.

Source of the pigment in the pigmented leucocyte.—If further evidence be required of the identity of the intraparasitic pigment and that found in the tissues, it will be supplied by a study of the fate of the pigment grains and clumps set free in the blood on the breaking-up of the segmented parasite.

If malarial blood, drawn during the rigor and early stages of acute attacks, and even at other times, be examined, large mononuclear leucocytes carrying grains or even blocks of black pigment may be encountered. If the observer be fortunate and persevering he will sometimes actually see whence this pigment is derived; he may even detect the leucocytes in the act of taking it up. He may see the pigment set free in the liquor sanguinis by the falling to pieces of a segmenting parasite; and he may then see a phagocyte creep across the field of the microscope and slowly engulf the little block. This undoubtedly is a principal source of the pigment in the leucocytes. Other, though possibly less important, sources are the effete gametes and, especially in the large cells of the spleen, necrosed parasite-containing red blood-corpuscles.

Phagocytosis in the spleen.—The evidence of phagocytosis in the spleen in malaria is very remarkable. Not only are large and small masses of hæmozoin included in the macrophages, in the smaller cells, and in the endothelium, but entire blood-corpuscles, sometimes as many as eight or nine, mostly containing parasites, besides free parasites, free hæmozoin, and fragmented hæmoglobin, are frequently to be seen in one and the same phagocyte. Sometimes one hæmozoin-laden phagocyte may be seen included in another phagocyte, and these perhaps in a third.

Blood of the splenic vein and liver.—Of all the vessels of the body the splenic vein is that in which malarial pigment is most abundant. Whereas in other vessels it is found to be included in ordinary leucocytes,

in this vessel it is included, not only in the leucocytes, but also in certain large white cells identical with those occurring in the spleen, and, doubtless, of splenic origin also. Similar cells may be found in the capillaries of the liver, rarely, however, in the blood beyond this organ; that is to say, they are filtered out by the liver from the blood carried to it by the splenic vein. An additional reason for the abundance of hæmozoin in the splenic vein is, that not only is the spleen the physiological destination of many of the hæmozoin-laden leucocytes and effete parasite-infested corpuscles, but it is likewise a favourite nursery for the parasite. In fact, the parasite is present in this organ in greater profusion than elsewhere. Hence it is that the splenic vein, coming direct from a rich breeding- and dumping-ground, contains a large number of hæmozoin-laden leucocytes.

Extravascular pigment.—In the early stages of malarial disease, except in the case of the spleen and the bone marrow, pigment is entirely confined to the lumen of the vessels and to their endothelium. But if we examine tissues from a case which has died at a late period of the disease, the pigment may then be found, not only in the endothelium, but also in the walls of the vessels, and even in the perivascular lymph spaces, whence, it may be inferred, it is subsequently carried to the lymphatic glands to be finally dealt with and broken up. As encouraging this view about the ultimate fate of the malaria pigment, Kelsch has pointed out the significant fact that the lymphatic glands in the hilum of the liver are always markedly pigmented in old-standing malarials; a fact evidently referable to the disposal of the large quantities of hæmozoin which, as we have seen, the liver filters out, more especially from the splenic portion of the portal stream.

These facts explain malarial pigmentation and oligocythæmia.—The facts just mentioned explain the origin and nature of malarial pigmentation, and also, in part at least, the oligocythæmia of the malarial state, which, as pointed out, is only partially accounted for by the destruction of corpuscles by the

parasite in the general circulation as represented by finger blood. They show that what is seen in finger blood does not represent anything like the aggregate mortality that is going on among the corpuscles from direct destruction. The principal part of the malarial drama is played out in the spleen, liver, bone marrow, brain, etc., and not in the general circulation. What is seen in finger blood is but an overflow, as it were, of the greater drama going forward in the viscera.

The yellow pigment.—Besides the pathognomonic black pigment (hæmozoin), there is usually found in the organs a greater or less amount of a yellow or brown pigment (hæmosiderin), the "pigment ochre" of Kelsch and Kiener. This pigment is found not only in the capillaries, but also, and in greatest abundance, in the parenchyma cells of the liver, spleen, pancreas, kidneys, as well as in the bone marrow and in the connective tissues. It is not characteristic of malaria, but occurs in all morbid processes in which there is extensive breaking-up of erythrocytes, as in paroxysmal hæmoglobinuria, in pernicious anæmia, in extensive burns, in poisoning by pyrogallic acid, potassium chlorate, arseniate of hydrogen, and many other toxic agents. It has peculiar chemical properties, being equally insoluble in acids, in alkalis, and in alcohol. At first, when freshly deposited, it gives no evidence, under the usual micro-chemical tests, of containing iron; after it has been in the tissues for some time it appears to be altered in character in this respect, and it then gives a ferrous reaction with ammonium sulphide, and with the double cyanide of iron and potassium.

Polycholia and hæmoglobinæmia.—Under ordinary conditions of physiological waste the products of the effete blood-corpuscles are converted into bile pigment, and so got rid of. Up to a certain degree of pathological hæmoglobinæmia the liver can deal in a similar way with free hæmoglobin; so it comes about that, when this substance is free in the blood in unusual abundance the secretion and flow of bile become correspondingly increased. If this flow

of bile be excessive it gives rise to what are called "bilious symptoms"—bilious vomiting, bilious diarrhœa—symptoms which are so common in malarial disease, particularly in that variety known as "bilious remittent." Thus, polycholia is a constant and often urgent feature in most malarial fevers, and is good evidence that in malarial infections there is a surcharge of the blood with free hæmoglobin. It is not improbable, although this point is disputed, that the yellowness of the skin and scleræ observed in these fevers is due to tinting by free hæmoglobin, to a hæmoglobinæmia in fact, and not, as is popularly believed, to biliousness or cholæmia from bile absorption.

The yellow pigment is deposited in excessive hæmoglobinæmia.—As in those other conditions referred to as being attended by rapid hæmolysis, in severe malarial fevers in which there is great and sudden liberation of hæmoglobin which the liver cannot at once deal with, pending its transformation into bile pigment the liberated hæmoglobin is taken up by the protoplasm of the cells of the different tissues and organs of the body, and precipitated in them in a slightly altered form; it is stored up, in fact, waiting to be worked off as bile pigment by the, for the time being, overtaxed liver. The yellow pigment is, in all probability, this precipitated hæmoglobin.

Great excess of hæmoglobinæmia results in hæmoglobinuria.—Should the liberation of hæmoglobin go beyond this, be too great and too suddenly effected for the excretory powers of the liver and the storage capacity of the tissues, then the hæmoglobin, little altered in composition, seeks a more speedy way of escape by the kidneys, and hæmoglobinuria is produced. This is what is found in ordinary paroxysmal hæmoglobinuria, and in toxic hæmoglobinuria; and in this way we may account for the peculiar features of the disease to be described later on—hæmoglobinuric fever.

Size and shape of the blood-corpuscles.—On the whole, in malaria, as in most anæmic conditions, the corpuscles are larger than normal—particularly those attacked by the parasite, especially the tertian para-

site. Occasionally we come across genuine megalocytes, and, not infrequently, certain very minute, darkly-coloured spherical corpuscles, which may be nucleated and of embryonic type. Erythrocytes with basophilic stippling are not uncommon. Some pathologists regard these basophilic granules as evidence of degeneration of the erythrocytes; P. Schmidt, however, considers them as evidences of regeneration, since they are most numerous during recovery. There may be marked irregularity of outline in many of the corpuscles, and an indisposition to form rouleaux.

The leucocytes in malaria.—The leucocytes, especially the large mononuclear, play a very important part in malaria. In mild attacks their numbers, as observed in peripheral blood, decrease somewhat, both relatively to the red corpuscles and absolutely. In benign tertians and quartans their maximum is attained, according to Billings, two or three hours after the onset of chill. From this time there is a progressive diminution until the minimum is reached at the end of the paroxysm and when temperature has become subnormal. After this the number rises somewhat, and during the interval occupies a position midway between the maximum and minimum. The large mononuclear elements are increased, both absolutely and relatively. Sometimes the mononuclear are as numerous as the polynuclear leucocytes, especially during apyrexia. A mononuclear leucocytosis of 15 per cent. and upwards, Christophers and Stephens regard as strong evidence of a malarial infection. With regard to the leucocytes in that type of fever which is caused by the crescent-forming small parasites, it is impossible, Billings says, to arrive at so definite a conclusion as in the cases of benign tertian. In the former type of case there appears to be a slight diminution in the number of leucocytes towards the end of the attacks, a diminution which is made good during the interval. Curiously enough, in certain severe pernicious attacks there is a decided increase of the leucocytes in the peripheral blood—sometimes an

enormous increase, a positive leucocytosis, the normal 8,000 per c.mm. rising to 10,000, or even to 30,000, the proportion to red corpuscles rising from the normal 1 in 500 or 600 to 1 in 300, or even to 1 in 70.

The cause of fever and of periodicity in malaria.—The cause of fever in malaria is some toxin or toxins liberated when the segmented parasites break up in the blood. Rosenau and others, by injecting filtered blood-serum procured during the cold stage of an ague, have succeeded in demonstrating the presence in the blood of such a substance.

The cause of the periodicity is doubtless of a twofold character, the first and most important being the more or less fixed life-span of the parasites, and the second some physiological property in the human body which tends to destroy the parasites. Like so many physiological phenomena, this malaria-destroying principle or force has a tendency to quotidian increase and decrease. Although sometimes almost powerless to cope with the parasites, it usually brings about, especially after repeated infections, a more or less complete immunity.

It might be urged that though such an explanation may be applicable to quotidian periodicity, it could not apply to tertian or quartan periodicity. This cannot be admitted. If there be a regular quotidian occurrence of susceptibility to the malaria germ, this susceptibility must be existent on the second and third day as well as on the first; therefore a tertian parasite, on maturing, will encounter it on the second day, and a quartan on the third, just as certainly as if they were daily-maturing parasites.

This hypothesis may be a wrong one. But it will not be without its use if it impress the importance of placing malarial patients under tonic influences as an aid to specific treatment; and of protecting the subjects of malarial recurrences from debilitating influences. For, just as tonic influences may suffice to cure a fever, so, in many malarials, depressing influences are sufficient to provoke relapse: presumably by weakening the physiological element which holds the infection in check.

CHAPTER V

MALARIA: MALARIAL CACHEXIA, ETC.

MALARIAL cachexia is the term applied to a group of conditions, more or less chronic, believed to be the result of an antecedent attack of severe malarial fever, or of a succession of such attacks, or of prolonged exposure to malarial influences.

Undoubtedly many of the more or less chronic morbid conditions which were formerly attributed to the malaria parasites are the outcome of infections by trypanosomes, by the Leishman body, by spirochætes, or by some as yet unidentified protozoal organisms.

Symptoms.—The leading symptoms are those of a special kind of anæmia, characterized objectively by a peculiar earthy sallowness of skin, somewhat yellow sclerotics, enlargement of the spleen and—in the early stages at all events—of the liver. Usually the subject of this cachexia is liable to frequent attacks of an irregular type of fever, particularly after exposure, or fatigue, or, in fact, after any unusual physiological strain.

Malarial cachexia without fever.—It should be mentioned that fever is not a necessary antecedent or accompaniment of malarial cachexia. In highly malarious countries it is not unusual to see typical examples in which fever had never been a feature, or, at all events, had been of so mild a character as not to have seriously attracted attention, or had occurred in childhood and been forgotten.

Enlarged spleen.—In such countries a large proportion of the population have enormously enlarged spleens. The traveller cannot fail to be struck by the number of people he sees with big bellies and spindle shanks; by their languid and depressed air; their sallow, dry, rough, unhealthy-looking skins. In

many malarial cachectics the skin pigmentation is remarkably dark; patches of almost black pigmentation are also sometimes discoverable on the tongue and palate.* It is said that in some intensely malarial places children are occasionally born with enlarged spleens, as if the malarial poison had already affected them in utero. I cannot personally vouch for this, but I have often seen very young children with bellies enormously protuberant from distended spleen. According to Scheube, De Freytag and Van der Elst observed in 1873 and 1878 in Atchin that all the children born were affected at the time of birth with malarial cachexia, and that most of them died in a few months. Bein and Kohlstock found malaria parasites in the blood of the four-months-old child of a malarial mother, born some time after the arrival of the latter in a non-malarial district. Bignami failed to find malarial parasites, malarial pigmentation, or other sign of paludism in the fœtus of a woman who died of a pernicious malarial attack—an observation which has been repeated and confirmed by other pathologists. Although unusual, more recent observations have shown that infection of the fœtus in utero through the maternal circulation does occasionally occur, presumably through rupture of the placental attachments, or, possibly, diapedesis of infected corpuscles.

Delayed development. — In some instances of malarial cachexia of early development the general growth of the body is stunted and puberty retarded. I have seen a malarial cachectic who, although 25 or 26 years of age, had the stature and sexual development of a child of 11 or 12. Abortion and sterility are common effects of malarial cachexia, which, in this and in other and more direct ways, becomes a potent agent in repressing population.

Acquired tolerance of the malarial toxin.—In many instances, although the state of cachexia may have attained an excessive degree, ague, or, in fact, fever of any kind, has never been a prominent

* Observations in India tend to show that this condition, melanoglossia, is racial and not pathological.

symptom. It would seem that the body can become accustomed to the fever-producing toxin of the malarial parasite, much in the same way that it may become accustomed to opium and many other organic poisons. I have watched for three weeks the rhythmical development of a tertian parasite in a sailor who, although previously the subject of frequent attacks of ague, was quite free from fever during the period that I had him under close observation. Just as in those habituated to the use of opium a full dose of the drug, which in the unhabituated would produce profound or even fatal narcosis, acts merely as a gentle stimulant, so in those constantly exposed to, and actually infected with, malaria from infancy, the poison sometimes fails to act as a febrogene. And, to continue the comparison, just as the habitual use of opium produces a species of chronic poisoning or cachexia without narcosis, so the habitual presence of the malaria toxin may produce its peculiar cachexia without giving rise to fever. As a rule, however, particularly in the case of Europeans forced to reside in highly malarious countries, attacks of fever are of frequent occurrence in malarial cachectics.

Malarial neuroses and skin affections.—Superadded to the febrile attacks, and to the associated anæmia, we may meet in cachectics with a variety of functional troubles. One characteristic of most of these functional troubles is the periodicity they generally observe. Thus we may have quotidian, tertian, or quartan neuralgias, gastralgias, vomiting, diarrhœa, headaches, attacks of palpitation, of sneezing, and so forth. Besides these, skin eruptions—such as herpes, erythema nodosum, patches of lichen planus, eczema, urticaria, possibly synovitis—exhibiting a periodic liability to exacerbations and an amenability to quinine, have been noted in malarial conditions.

Peripheral neuritis.—I frequently see cases of well-marked peripheral neuritis, especially in patients from the West Coast of Africa, whose symptoms have been attributed to malaria. The degree of paresis varies from total inability to stand to weakness

merely. There can be no question about the antecedent malaria, but whether the neuritis in every instance be the direct result of this infection it is hard to say. Lately I saw a well-marked multiple peripheral neuritis, in which there was slight fever with abundant subtertian parasites, promptly subside on the administration of quinine. In this case the neuritis began with violent cramps in the legs. Loss of memory, partial or complete, appears to be a common accompaniment of this condition.

Herpetic eruptions are very common in malarial attacks. According to Powell, in Assam the appearance of a patch of herpes somewhere about the body, usually the lips, is regarded as an infallible sign that the attack of fever is over for the time being.

Hæmorrhages. — In high degrees of cachexia hæmorrhages of various kinds are apt to occur; in such conditions epistaxis, hæmoptysis, hæmatemesis, melæna, retinal hæmorrhages, purpura, occasionally hæmaturia or hæmoglobinuria are not infrequent. In such patients trifling operations—tooth extraction, for example—may prove a dangerous matter. I have seen in malarial cachectics hæmorrhages from the latter cause which were very difficult to control. Care must therefore be exercised in advising and in performing even the slightest operations on patients of this class.

Intestinal and pulmonary affections.—In addition to the troubles mentioned, we find that the subjects of malarial cachexia are apt to be dyspeptic; to suffer from irregularities in the action of the bowels; to suffer from morning diarrhœa, at first of dark bilious, and later, perhaps, of pale, copious, and frothy stools. They are also very liable to a low and highly fatal form of pneumonia.

Cachexia associated with functional and with organic lesions.—There may be said to be two degrees or kinds of malarial cachexia. In one there is merely anæmia with congestion of the portal system; this may be quickly recovered from on the patient being removed from endemic malarial influences and subjected to specific and proper treatment. In the other

there is, in addition to anæmia, organic disease of the abdominal viscera—of the liver, spleen, and kidneys—the outcome of long-standing congestion of these organs. These tissue changes not only keep up the anæmia, in spite of removal from malarial influences, but, in the long run, inevitably progress to a fatal issue.

Pathology and pathological anatomy.—The pathology of malarial cachexia is virtually, in the first instance, that of acute malarial disease. There is blood destruction by the direct action of the malaria parasite and of its toxins, eventuating in oligocythæmia and in the deposit of hæmozoin and of hæmosiderin (yellow pigment) in the tissues. The activity and persistence of the process lead to congestion which ultimately determines organic changes in liver, spleen, kidneys, and probably in the bone marrow.

Splenic enlargement.—The spleen may become so enlarged under repeated attacks of the congestion attending a succession of fever fits, or in consequence of a less active and perhaps feverless hæmolysis, that it may come to weigh many pounds, and so to increase in bulk as to occupy nearly the entire abdomen. The capsule of the gland, particularly on its convex surface, is thickened, and, perhaps, the seat of fibrous patches, or even of adhesions to neighbouring organs. Many of the trabeculæ forming the framework of the gland become greatly hypertrophied. On section, the tissues of such a spleen are found to be moderately firm, and usually of a reddish-brown colour; but when death happens soon after or during a febrile attack, the section of the gland shows a dark surface from deposit of hæmozoin, the pulp at the same time being softened. Perhaps from over-distension some of the vessels in the interior of the gland give way, and then there is a breaking down of the spleen pulp in patches, the remains of splenic tissue floating about in the extravasated blood. Microscopical inspection of these hypertrophied spleens, especially during fever, shows the black and ochre pigments in the situations already indicated.

"*Splenic index.*"—There are practical points in connection with malarial spleen which deserve mention. The relative absence, or prevalence, of these enlarged spleens or "ague cakes" in the native population is an excellent rough indication of the salubrity or the reverse, as regards malaria, of any particular district. Wherever they are common the district is malarious and therefore unhealthy, perhaps to Europeans deadly, and should be looked upon as extremely unfavourable for camping or residential purposes.

Liability to rupture of splenic tumours.—Another practical point is that these enlarged spleens are easily ruptured by a blow on the belly. In hot and malarious countries many a coolie goes about doing his work although he has an enormous spleen. This is a fact to be remembered in administering even mild corporal punishment to natives of malarious countries. Europeans have more than once been tried for manslaughter in consequence of neglecting it. Owing to this liability to rupture, the subjects of splenic enlargement must not be allowed to play at violent games, as football or even cricket, or at any game in which the diseased organ is exposed to a blow. Apart from direct violence, an enlarged spleen may rupture spontaneously, owing to sudden accession in size in the course of a fever fit.

Splenic ruptures are, of course, generally fatal. It sometimes happens that the presence of adhesions limits and restrains the hæmorrhage. Localized hæmorrhages of this description may, in time, lead to splenic abscess.

Hepatic enlargement.—Like the spleen, the liver in malarial cachectics becomes enlarged during accessions of fever. Under the influence of a succession of acute attacks, hepatic congestion may gradually acquire a more or less permanent character. After death from such fevers the capsule of the liver is found to be tense; on section the highly vascular tissue of the organ is seen to be reddish-brown or almost black, according to the degree and kind of pigmentation. If this stage of congestion be long maintained, it tends to bring about various kinds and

degrees of chronic hepatitis with hypertrophy of the intralobular connective tissue, and in time leads to hypertrophic or to different forms of atrophic cirrhosis. Thus irremediable organic disease of the liver, portal obstruction, and ascites may ensue.

Siderosis.—It is in livers of this description that a form of what is called *siderosis* is produced—a condition resulting from chemical changes undergone by the yellow pigment with which the various cells of the organ are charged. It has already been stated that, when first deposited, this pigment gives no ferrous reaction with ammonium sulphide, or with the double cyanide of iron and potassium; and that, as the deposit becomes older, chemical changes ensue, resulting in the elaboration of a form of iron which will then yield the characteristic black colour with the former, and blue colour with the latter reagent. Treated with ammonium sulphide, sections of liver, and also of spleen, kidney, and other hæmosiderin-charged tissues, from chronic malarials, may turn almost black to the naked eye, or, at all events, exhibit under the microscope abundance of blackened pigment. In such sections it is seen that the hæmosiderin is no longer in minute grains, as when first deposited, but in blocks and globules as large as, or even larger than, blood-corpuscles. This pigment is, of course, something quite apart from the parasite-derived hæmozoin deposited in the same organs.

Practical considerations.—Certain clinical facts about malarial hepatic congestion and malarial hepatitis are of importance. (1) Such conditions do not tend to terminate in suppuration; (2) they are almost invariably associated with splenic enlargement. These are important facts to recollect when it becomes a question of the diagnosis of malarial hepatitis from abscess of the liver. Another important fact to remember is that recent malarial enlargement of the liver is usually curable, depending, as a rule, on simple congestion; whereas old-standing malarial hepatic enlargement is usually incurable, depending, as it usually does, on hypertrophy of the connective tissue and a cirrhotic condition of the organ.

Malaria a cause of nephritis.—Changes similar to those found in the liver in the course of, and in consequence of, malarial disease occur in the kidney; in time they result in confirmed Bright's disease. Hence, probably, the frequency of Bright's disease in some highly malarious climates. In the *British Guiana Medical Annual*, Daniels mentions that in 926 post-mortem examinations in the hospital at Georgetown, Demerara, a highly malarial district, he found evidence of disease of the kidneys in no fewer than 228.

Cardiac degeneration.—As a consequence of defective nutrition from prolonged anæmia and recurring fever, the muscular tissue of the heart in chronic malarials may degenerate, the ventricles dilate, and, in time, the lower extremities become œdematous. For the same reason the subjects of valvular affections of the heart, whether compensated or otherwise, are unsuitable for residence in malarial countries.

Other sequelæ.—These include dysenteric conditions, forms of diarrhœa, low forms of pneumonia readily set up by chill and prone to terminate in abscess of the lung or to become associated with empyema, extensive sloughing phagedæna, and other forms of gangrene such as noma; or pernicious fever may supervene at any time and rapidly carry off the subject of advanced malarial cachexia.

Tubercular and syphilitic disease not infrequently concur with malaria; in fact, the latter may powerfully predispose to local manifestations of either of the two former, and vice versa—a complication as to which the practitioner must be on his guard.

CHAPTER VI.

MALARIA: ETIOLOGY

In considering the **etiology** of malaria two things must be carefully distinguished: (1) the circumstances leading to the invasion of the human body by the malaria parasite; (2) the circumstances determining the clinical manifestation of such invasion.

Circumstances favouring Infection

In the mosquito-malaria theory, now thoroughly established, we have the key to this problem. Whatever favours the presence and increase of the malaria-bearing species of mosquito tends to the increase of malaria, and vice versa; whatever favours the access of these insects, and the parasites which have passed into them, to the human body favours the acquisition of malaria.

It must not be forgotten that the malaria parasite, after giving rise to fever within a few days of its original invasion of the human body, tends to pass into a latent condition from which it wakes up into clinical activity again only after longer or shorter intervals; further, that in rare instances the clinical evidence of a successful malarial invasion may be delayed for months or, perhaps, for years. Consequently, the particular circumstances in which any given malarial attack declares itself are not necessarily those which led to the acquisition of the infection originally. Therefore, in regard to the etiology of malaria, fevers of first invasion have a significance very different from that pertaining to relapses or recurrences.

Geographical range.—The geographical range of malaria is very great; it extends in the northern hemisphere from the Arctic Circle to the Equator, and in the southern probably as widely. Malaria is not uniformly distributed throughout this vast area. It

[illegible] or [illegible] endemic foci which tend, speaking generally, to be more numerous and larger as the Equator is approached.

Influence of latitude and season.—In colder latitudes the association of malaria with swamps is marked, in warmer latitudes this association is [illegible] less apparent. In colder latitudes the type of disease is milder; in warmer latitudes it is apt to be more severe. In certain warm countries, as in Argentine and many of the islands of the South Pacific, malaria is entirely absent, or [illegible] and rare. In colder latitudes it is active only during the summer or early autumn; in warmer latitudes it is perennial, certain seasons—usually, though not invariably, the warmer, or after the rains—being the more malarial.

Influence of local conditions.—The strip of low, waterlogged country lying along the foot of mountain ranges, the deltas of large rivers, the pool-dotted beds of dried up streams, areas of country which have just been cleared of cultivation, recently deforested lands, are, in many instances, notoriously malarial. Well-drained [illegible], and carefully cultivated districts, as a rule, are healthy. There are, nevertheless, instances of [illegible] land, and sandy plains which, under certain [illegible] conditions, are intensely malarial. Towns are [illegible] less malarial than villages or the open [illegible].

Ship malaria. Although several instances are [illegible] of outbreaks of what was reputed to be [illegible] on shipboard on the open sea, many epidemiologists venture to accept the diagnosis as to the nature of these outbreaks, and maintain that malaria is never contracted away from the land. Mosquitoes haunt ships for some time after the latter leave port. If they are infected with the malaria parasite when they first enter the ship, or if they ingest the parasite after coming on board, they may very well communicate malaria.

Endemic and epidemic fluctuations.—From time to time malaria extends beyond its endemic foci, spreading in epidemic form over large tracts of

what is usually healthy country. There are a few well-authenticated instances of countries (Mauritius, Réunion) which, although previously exempt, subsequently became endemically malarial; and there are many instances of countries previously malarial which afterwards, especially under the influence of cultivation and drainage, became salubrious.

These circumstances evidently have reference to the distribution of species of malarial mosquitoes. Like other insects, mosquitoes occasionally, under specially favourable conditions, increase enormously in numbers and spread out in every direction. New species, which may belong to the malaria-bearing kinds, may be introduced into places where they formerly did not exist, just as *Culex fatigans* has been introduced into Australia. I believe a mosquito capable of subserving the malaria parasite was introduced in this way in the early 'sixties into Mauritius, an island whose fauna and flora had been hitherto very peculiar and special. In this way we can account for the outbreak of the great epidemic of malaria that swept over that formerly healthy island, and also for its present endemic insalubrity. A similar misfortune may very well happen to the non-malarious South Pacific islands in the near future.

The exemption of certain islands from malaria, even though in the midst of an archipelago of malaria-haunted islands, is a very remarkable circumstance. Barbados is an instance in point. Low has confirmed the popular belief that malaria is unknown there as an indigenous disease, and points to the absence of Anophelinæ as the explanation. But how explain the absence of Anophelinæ, seeing that Culex abounds and all the conditions favouring mosquito life are present? The disappearance of malaria from Britain is another remarkable, and perhaps not fully explained fact. Anophelinæ still abound in many places, yet the endemic malaria has vanished. It may be that the general use of quinine and the improved domestic hygiene have to be credited with this. Still more remarkable is the circumstance that there are villages and districts

India, as pointed out by Christophers and Stephens, and similar districts in Italy, as pointed out by Celli, in which, though surrounded by highly malarious country and though Anophelinæ abound, there is no malaria. The explanation of this anomaly is not apparent. Perhaps in these places there is some local substance on which the mosquitoes feed that is fatal to the parasite. Sambon ingeniously suggests that there may be special local conditions that favour *hyperparasitism*, that is, the attack and destruction of the malaria parasite by some other kind of parasite. Similar occurrences are common enough in nature. In support of this view he cites Ross's observation of what he designated "*black spores*" (Fig. 22), bodies which are now known to be protozoal organisms belonging to the genus Nosema. These "black spores" prey on the malaria oöcyst in the wall of the mosquito's stomach and destroy it, just as they prey on the larvæ of *Filaria immitis* encysted within the Malpighian tubes of the mosquitoes which subserve their development. Whatever the explanation of the salubrity of these mosquito-haunted plains be, it is well worth searching for; it may be that it would carry a hint of value in attempting the prevention of malaria.

Fig. 22. — Ruptured oöcyst containing Ross's black spores. (*After Grassi.*)

Atmospheric temperature.—One of the most important conditions necessary to the sporogonic phase of the malaria germ is a sustained average temperature of at least 60° F. The malaria parasite will not develop in the mosquito at low temperatures.

Altitude.—Altitude *per sè* has, apparently, no influence on malaria. It is the decrease in temperature, usually implied by an increase in altitude, that is the real determining circumstance in bringing about a diminution in the prevalence of malaria in uplands. In the tropics an elevation of six or seven thousand feet may not secure immunity from malaria unless there be, at the same time, a corresponding and

sufficient lowering of temperature. In Italy there are many malarious spots high up among the hills; the same is the case in India and elsewhere in those elevated valleys which are also narrow, imperfectly ventilated, and imperfectly drained.

Moisture.—Another important condition for the production of malaria is the presence of water. In the Sahara there is no malaria unless in the oases; in many of these it is rife—in Biskra, for example. A large expanse of water is not favourable to malaria. The mosquito thrives best in sluggish streams with grassy banks and many backwaters; still better, in small pools or other collections of water, as in broken bottles, empty tins, etc., where there are no fish to prey on their larvæ, and where the surface is not agitated by winds. One such puddle near a house may suffice to render that house unhealthy.

Decomposing vegetable matter.—It is customary to add yet another condition as being necessary to the existence of malaria—namely, the presence in the soil of a notable amount of decomposing organic matter, particularly vegetable matter. But that this is not an indispensable condition is proved by the fact that there are many almost barren spots in which malaria abounds.

Other conditions necessary.—The concurrence of these conditions, high temperature and moisture, even though associated with abundant vegetation, is not sufficient to generate or support malaria; for there are many places in the world—the Argentine and the islands of the South Pacific, for example—in which high temperature, moisture, and decaying vegetable matter are present but in which malaria is almost unknown. Manifestly there are other and more complicated conditions which are equally indispensable, and which must concur with heat and moisture in order to secure the presence of malaria-bearing mosquitoes. What these conditions are it is as yet impossible to say.

Influence of subsoil moisture.—The state of the subsoil as regards moisture appears to have considerable influence on its malaria-producing properties.

Short of general overflow, the higher the subsoil water the greater the chance of a given locality supplying breeding-places for mosquitoes and therefore of proving malarious. Hence arises marked liability to epidemics of malaria on the subsidence of extensive floods; and hence the danger attending the raising of the level of the subsoil water by irrigation works, canals, embankments, and other engineering works.

Influence of rainfall.—As regards the relation of the prevalence of malaria to rainfall there have been too many generalisations based on the limited experience of one or two districts. Thus, it is often said that the most malarious time of the year is at the end of the rains, when the soil is beginning to dry up. A wider view of the subject shows that, though applying to some places, this statement does not apply to all. There are localities where the fever curve is highest before the setting in of the rains. In some places, particularly in those that are low-lying, flat, and swampy, fevers of first invasion disappear almost entirely when the country becomes flooded. This apparent want of a universal and definite relationship of fever curve to rainfall indicates that the conditions determining the prevalence of malaria are highly complex, and that they are not by any means merely a matter of heat, moisture, and vegetation. In some places much rain will scour out the mosquito pools; in other places it will just fill them. The key to the explanation of the varying relation of malaria to rainfall is to be found in the influence of the latter on the local mosquito pools.

Influence of winds and atmospheric diffusion.—It has been said that the wind can carry the malaria germ great distances, roll it along the ground like thistledown, and even force it to ascend high mountains. It is very doubtful, however, if the malarial mosquito can be transported, in this way, very far from its native pool. The mosquito does not ascend more than a few feet from the ground, and in high winds, or even in draughts of air, such as that from a

punkah, immediately seeks shelter. It is certain that some thousand or fifteen hundred yards of water between a ship and a malarious coast may suffice to secure immunity to the crew. The experience of the notorious Walcheren expedition proves this. A similar distance on land from a malaria source is probably approximately as effective. The diffusion of malaria by winds is generally extremely restricted. Inside, a city may be quite healthy, whilst outside the walls the country may be pestilential. One village may be sickly, whilst a neighbouring village may be healthy. Surely, if winds transport the malarial germ for any distance from its source, there would not be so great a difference in the relative salubrity of urban and suburban localities, nor of neighbouring houses and villages. Neither does the malaria germ ascend to any great height above the ground. Acting on the empirical observation of this fact, the peasants in many unhealthy spots in Italy and Greece are said to secure a remarkable degree of immunity by passing the night, during the fever season, on platforms raised on poles a few yards above the ground. It seems safe, therefore, to conclude that the horizontal and vertical diffusion of the malaria germ—that is to say, of the mosquito—is, as a rule, very restricted.

Influence of trees, houses, and lodging.—The intervention of a belt of trees between a malarial swamp and a village is said to protect from malaria the houses on the leeward side of the trees. The trees may filter out the mosquitoes by affording them protection from winds. Open windows and doors, by giving ready access to mosquitoes, are sources of danger in malarial countries; for this and similar reasons sleeping on the ground, on the ground floor, or unprotected by a mosquito curtain, is dangerous.

Time of day in relation to infection.—Evidently in conformity with the habits of the mosquito, the time just before sunrise and just after sunset, and the night, have the reputation of being the most dangerous as regards liability to contract the infection. Although mosquitoes are most active during twilight and night, they bite readily enough during the daytime

in shady and windless places, as in thick jungle or in a dark room. A very few species are diurnal in habit.

Disturbance of the soil.—It has often been observed that in malarious countries, so long as the soil remains undisturbed, agues and the severer forms of fever are comparatively rare; but so soon as building, road-making, and other operations implying soil disturbance commence, then severe malarial fevers appear. After a time when, in the progress of events, these operations have concluded, and the broken surface of the soil has, so to speak, skinned over again, the place becomes once more comparatively healthy. The medical history of Hong Kong may be cited in illustration of this fact. At the commencement of the occupation of this island by the British, for a short time it was healthy enough. Then, on its cession being completed, and when barracks and houses were being built and roads laid out, it became excessively unhealthy, the soldiers dying by the hundred of pernicious fevers. In time the sickness and mortality gradually decreased; and now, so far as malaria is concerned, the city of Victoria is healthy. But, even at the present day, wherever in the outskirts, in the course of the construction of houses, roads, forts, and similar works, soil is turned up, fever—often of a most pernicious type—is nearly sure to break out among those engaged in the works. I cite the case of Hong Kong; but there are dozens of other instances which might be quoted, and which are quite as apposite and convincing, as to the danger of carelessly disturbing the soil in malarious localities, particularly during the warm season. Soil disturbance usually implies the formation of holes. Holes imply puddles, and puddles imply mosquitoes. Workmen from many districts, some of them malarious, are assembled in crowded lodgings; one infected workman suffices to start the epidemic. In the present state of knowledge this seems to be adequate explanation of the recognized danger of earth-cutting in malarious districts.

Circumstances favouring the Clinical Manifestation of Malarial Invasion

As a rule, a successful malarial infection declares itself within a week or ten days. As with other infections, certain individuals resist the pathogenic influences of the malaria parasite for a longer period. A very few appear to be permanently immune. Everything tending to cause physiological depression favours susceptibility and acute manifestations.

Influence of meteorological conditions on relapse.—A malarial subject while in the mild climate of the tropics may keep in fair health; but when, as is so often the case with sailors and others returning to Europe, he is plunged into the stormy winter of the North, is exposed to cold, and has long watches and fatiguing work, very probably latent malaria will become active and ague follow. This is a common experience with malarials from the tropics. It is almost the rule with people coming from the West Coast of Africa. Stanley remarks that so long as he and his companions were ascending the Congo, the wind being with them and therefore not much felt, they did not have fever; but that on descending the stream, a strong breeze blowing in their faces and chilling them, they constantly had attacks. The physiological depression and disturbances caused by the cold wind paralysed the self-protecting power of the body, and permitted the hitherto latent parasite to get the upper hand. And so it is found, in the highly malarial districts of tropical Africa, that houses perched on elevated and windy situations are not so healthy as those on lower and, therefore, less exposed and more sheltered ground. This must not be interpreted as showing that wind causes or carries malaria. The wind merely acts as a cause of physiological strain, of chills; it acts just in the same way as fatigue, hunger, a wetting, disease, fear, excesses, or depressing emotions are found to do.

Sex, age, occupation.—Sex *per se* seems to have no particular influence as regards liability to or severity of malarial attacks. Neither has occupation;

although, of course, those engaged in tilling and working the soil are more exposed to mosquito bite, and therefore more subject to malaria, than the townsman or the sailor. Malarial attacks are more severe, more common, and much more dangerous in young children than in adults.

Malaria a communicable disease. — Malaria is certainly not directly communicable, in the same way that such diseases as smallpox or measles are. It can be communicated directly only by injection of malarial blood. But there can now no longer be any doubt that a malarial patient introduced into a community, provided suitable mosquitoes are present, is a source of danger. If mosquitoes of the proper species bite such a patient—say in the wards of a hospital, in a gaol, a house, or a camp—and a week later bite someone else, that second individual may become infected, and ten days later may be seized with malarial fever.

Study of the mosquito indispensable.—Full knowledge of all that concerns the etiology of the disease will only be attained when we have full knowledge of the various species of mosquito capable of subserving the germ, of certain vertebrates which may be capable of taking the place of man in the malarial cycle, of their geographical distribution, of their habits, and of their enemies. As yet this knowledge is but beginning. When we have said that the malaria parasite is subserved by several species of Anophelinæ and that these species are mainly of nocturnal habit, we have enumerated the principal items of existing knowledge on the subject. Whether certain species of Culex, Stegomyia and other Culicinæ are efficient hosts for the parasite, as some of them certainly are for *Plasmodium danilewskyi* and *Filaria bancrofti*, can as yet neither be affirmed nor denied. Studies in this field are being actively carried on, and important advances may be looked for.

Acclimatization and Immunity

Personal acclimatization.—Is there such a thing as acquired immunity as regards malaria? The

answer to this is, "Yes and No." As regards the European, it would seem that those who have resided many years in a malarious district are less liable than recent arrivals to severe remittents, but more liable to mild agues. As already mentioned, the first attack of malarial fever is generally remittent and severe in character; subsequent attacks are generally frankly intermittent. Old febricitants are more liable to pernicious attacks of an adynamic type than the recently infected. Trifling causes, such as do not provoke fever in the fresh arrival, are often sufficient to bring on an ague fit in the old resident. The new arrival in the tropics does not think much of exposing himself to the sun, the rain, and the wind; but the old resident is very chary about going out without his sun-hat and white umbrella. The latter wears flannel, and changes his clothes after exercise; he is careful not to cool off too rapidly by sitting in a draught; he will not sit down in wet clothes. The new-comer may look on these precautions against chill as signs of effeminacy. They are not so, however; experience has taught the old resident that neglect of them means an attack of fever and a week off work. The new-comer takes a cold bath; the old resident takes a warm one. The new-comer sits up late, eats and drinks and smokes as in Europe; the old resident goes to bed betimes, and eats and drinks and smokes in moderation. By and by, sharp lessons teach the new-comer to respect the sun and the rain and the wind, to clothe with a view to avoiding chill, and to live temperately. This is an education all pass through in malarial countries. "Acclimatization," to a great extent, though not entirely, means experience, education; not simply an unconscious adaptation of the physiology of the individual, but an intelligent adaptation of his habits.

Racial and individual differences of susceptibility. — Nevertheless, there can be no doubt that, for some occult reason, certain races and certain individuals are less susceptible to malarial influences than others. A very few individuals are absolutely immune and can live in intensely malarial places with impunity. It is a

well-established fact that the negro in Africa, although he does get fever, does not get it so frequently nor so severely as the European; even although the latter, from his hygienic ways of living, is of the two much the less exposed to infection. The Chinese, the Malays, and some other dark-skinned races also appear to enjoy a comparative immunity—an immunity considerably less pronounced, however, than that enjoyed by the African and West Indian negro. There is some evidence to show that even the individual European, if he survive the process, may after many years, through frequent infection, attain immunity; this, however, does not appear to be transmitted. The inhabitants of the malarious districts of Italy, Corsica, Greece, Turkey, and other South European countries have inherited no marked immunity from malaria in virtue of the thousands of years during which their ancestors lived in malarious districts. But they have inherited experience, and many of them know how to keep clear of the infection they cannot overcome; this probably is, in great measure, the extent of their acclimatization and apparent acquired immunity.

We are indebted to Koch for an important observation, with manifest practical bearings, on this subject; an observation which throws light on the apparent immunity of negroes, Melanesians, and other dark-skinned races living in highly malarious countries. He has shown, and his statements have been abundantly confirmed, that the natives of such districts acquire their immunity from repeated and persistent infection in childhood. In such places the blood of practically every child up to three or four years of age contains malaria parasites. The proportion of infected children gradually becomes smaller with each additional year, until adolescence is approached, when the blood becomes practically parasite-free, and immunity is established. Daniels had already shown, by a comparative study of the prevalence of malarial pigmentation in the cadavers of natives of British Guiana, that such was probably the case; Koch's more direct observations on the

parasite in Melanesia, confirmed as they have been by English observers in India and Africa, have definitely settled the matter.

The mortality in native children from malaria is very great; but it would appear that a relative tolerance is soon acquired, for although the negro child may have a rich infection of parasites in its blood, possibly in consequence partly of increasing immunity, partly of some racial and inherited quality, it may exhibit a remarkable tolerance of the malaria toxins. It has often been remarked that these dark-skinned children, with enormous spleens and a rich stock of malaria parasites in the blood, run about fever-free, and apparently in rude health. It would seem that certain races of men react to the malaria parasite much in the same way as the Texan cattle react to *Babesia*, or as the large game animals of Africa react to *Trypanosoma brucei*; repeated infection in early youth, if it does not quickly prove fatal, creates immunity. Race may have something to do with the tolerance of the infection; but it is not everything, for the negro from a non-malarial country on becoming infected in a malarial country suffers almost as severely as the European.

CHAPTER VII

MALARIA: DIAGNOSIS

THERE is a marked tendency to regard and diagnose all fevers occurring in tropical countries, or in individuals who have returned from tropical countries, as malarial. Such slovenliness in diagnosis must be strenuously avoided by the practitioner. It is apt to become a habit which, sooner or later, is bound to have disastrous consequences.

At the same time the opposite error of overlooking malarial infection must be equally guarded against. In many tropical and sub-tropical localities practically every European is, or may be, the subject of active or latent malaria. The tropical practitioner should therefore approach the diagnosis of all his cases, no matter what, with the idea ever present to his mind that they may be malarial or complicated with malaria.

The three pathognomonic signs of malaria.—These are—periodicity; the effect of quinine; the presence of the malária parasite.

The diagnosis of malarial disease, if all the means at our disposal be employed, is usually not a difficult matter. Formerly, periodicity and the effect of quinine were the tests principally relied on. In certain circumstances they are fallible. Nowadays, in all doubtful and serious cases, it behoves the practitioner to have recourse to the least fallible test—the microscopical examination of the blood. When such an examination yields a positive result, when the parasite in any of its forms, or its characteristic product—hæmozoin—either free in the liquor sanguinis or enclosed in leucocytes, is found, the diagnosis of malaria is securely established. Negative results from a single microscopical examination are not so trustworthy as

positive; but if the practitioner has experience, and if he has the opportunity to make his examinations at suitable times and in a case untreated by quinine, they, too, are conclusive, more especially if supplemented by a differential count of the leucocytes.

The quinine test is generally conclusive in intermittents and in the various larval forms of malaria, but the more severe types of remittents are often singularly resistant to the drug. Moreover, time may not be available in which to test such cases with quinine. They may be cases of a threatening nature in which a speedy diagnosis is of the first importance. In such cases the microscope is the only available trustworthy diagnostic agent.

Periodicity in diagnosis.—Periodicity at times is a trustworthy enough clinical test for malarial disease. *Tertian and quartan periodicity occur only in malarial disease;* when either is thoroughly established, its presence is almost conclusive as to the case being malarial. It is otherwise as regards the significance of quotidian periodicity. Quotidian periodicity we find in greater or less degree in nearly all fevers, particularly in fevers associated with suppuration. In hectic conditions quite unconnected with malaria one often sees a quotidian afternoon rigor, followed by hot, dry skin, and a temperature rising even to 103° or 104° F., the febrile movement concluding with a profuse diaphoresis and complete morning apyrexia. Such cases are apt to be misdiagnosed and treated as malarial.

Periodicity of fever in liver abscess; diagnosis from malaria.—Particularly is this the case in suppuration connected with the liver—a condition peculiarly liable to occur in tropical practice. Simulation of malarial fever by hepatic abscess is very common; it is a pitfall into which the inexperienced tropical practitioner often tumbles. In consequence, we find that, at one time or another, most liver abscess cases are drenched with quinine, on the supposition that the associated fever is malarial. There are several points, even apart from an exam-

ination of the blood, which, if duly considered, will avert this blunder.

In hepatic abscess, although the liver is enlarged, the spleen is not necessarily so; splenic enlargement, though an occasional, is not a usual feature in liver abscess. In malarial fever if the liver be enlarged the spleen is still more so, and usually can be felt extending well beyond the costal margin. In hepatic abscess the fever occurs generally, though not invariably, in the late afternoon or evening; the patient may perspire profusely, independently of fever lysis, at any time of the day or night—very generally whenever he chances to fall asleep. In malarial fever the paroxysm may, and generally does, occur earlier in the day; there is no marked tendency to sweating unless at the defervescence of the fever. In hepatic abscess a history of dysentery is nearly always obtainable if carefully inquired for. If fever be distinctly tertian or quartan in type it is not hepatic. In all doubtful cases the blood must be examined once or oftener, the rigor stage or early hot stage being selected for the examination, and the examination being made before administration of quinine. Apart from the presence or absence of the parasite or of pigmented leucocytes, marked increase of polymorphonuclear leucocytes would be in favour of hepatic abscess; a relative excess of mononuclear leucocytes in favour, though not conclusive, of malaria. Occasionally cases are met with in which there is a history of malarial infection and, in addition to this, a history of dysentery, and the liver and spleen are both enlarged. In such cases diagnosis may be impossible without the microscope and the aspirator.

Diagnosis of bilious remittent from yellow fever.—In bilious remittent the icteric tinting of the skin is an earlier feature; albuminuria is not so common and generally not marked; temperature is maintained high for many days, not subsiding in three or four days as in yellow fever; the vomiting is profuse and bilious; the pulse does not become phenomenally slow as in yellow fever; in the initial

stage the eyes are not congested and shining to the same degree; and, of course, the parasite is to be found in the blood.

Diagnosis from other types of paroxysmal fever.—The following also are oftenmis taken for malarial fever: Cerebro-spinal meningitis; urethral fever; the fever attending the passage of gall-stones, or with inflammation of the gall-bladder; that associated with pyelitis and surgical kidney; lymphangitis, particularly that form of lymphangitis associated with elephantiasis and other filarial diseases; undulant fever; relapsing fever; trypanosomiasis; kala-azar, generally an irregular fever, though often quotidian, and almost invariably attended with enlarged liver and spleen and with anæmia; the fevers associated with tuberculous disease, with ulcerative endocarditis, with some types of pernicious anæmia, with splenic leucocythæmia, especially with visceral syphilis, with rapidly growing sarcoma, with forms of hysteria, and with many obscure and ill-defined conditions. The use of the microscope must not be neglected in such cases if there be the slightest doubt as to their exact nature.

It must not be concluded that, although unquestionable evidence of the presence of one or more of the foregoing has been obtained, malaria is absent. Malaria often concurs with these diseases. Malaria is a common complication in trypanosomiasis, for example, and it is often hard to pronounce as to whether in such cases any given rise of temperature be due to the trypanosoma or to the malaria parasite. The same may be said of tuberculosis, of syphilis, and, in fact, of any medical or surgical condition.

Typhoid fever.—Without the microscope it is sometimes impossible to diagnose typhoid types of malarial fever from genuine enteric. In both there may be diarrhœa or constipation; in both there may be splenic enlargement; in both there may be typhoid tongue, delirium, and the entire range of typhoid symptoms. As a matter of fact, until recent years all typhoid in India was regarded and treated a malarial fever—malarial remittent– and, doubtless

often with disastrous results. In circumstances where the Widal test is available it is an invaluable supplement to microscopical examination of the blood.

Typho-malarial fever.—One important fact in connection with the diagnosis of typhoid in malaria must ever be kept in mind. In individuals who have previously been subjected to malarial influences and who, perhaps, have suffered at one time from well-marked malarial fever, the oncoming of typhoid is often preceded by three or four paroxysms exactly like those of ordinary ague. This may occur even when the patient has been for some time in a non-malarial country, as England. In such cases quinine is usually given early in the attack; its failure to check the disease should lead to careful prognosis and the avoidance of too active purgation. Similarly, well-marked malaria-like fluctuations of temperature and the appearance of the parasites in the blood in the course of a continued fever do not exclude typhoid. These cases are probably typho-malarial, and have to be treated as such—as typhoid with a malarial complication.

Necessity for microscopical examination of blood in pernicious attacks.—Without the microscope it is sometimes impossible to diagnose, in time to direct appropriate treatment, pernicious comatose malarial attacks from heat-stroke or, if algide in character, from ordinary apoplexy; malarial dysentery, which must be treated with quinine, from ordinary dysentery, which must be treated with emetine, or ipecacuanha, or with the sulphates; algide malarial attacks, from cholera; certain types of malarial fever occurring, as it is very apt to do, in the puerperal state, from puerperal fever; malarial pneumonia, from croupous pneumonia; malarial aphasia, from the aphasia of organic brain disease; and so on.

It is manifest that the revelations of the microscope have enhanced our powers of diagnosis in malarial affections enormously, and, therefore, our powers of treatment. Every doubtful case must be tested by it. In many forms of malarial disease, if

life is to be saved, action must be prompt, decisive, energetic, and based on accurate diagnosis. The diagnosis of ordinary agues may be postponed for a day or two without much danger, and be made correctly enough without the microscope; but every now and again a pernicious attack is sprung upon the practitioner, the nature of which he must be able to recognize at once, and recognize with confidence. When the parasite is seen in the blood, it is surely known that there is a malarial element in the case and that quinine is indicated. Confidence in directing treatment is a great matter. It cannot, therefore, be too strongly urged on the tropical practitioner to avail himself of every opportunity to gain experience in the use of the microscope in blood examinations, and to take care to have a suitable instrument in working order and available at a moment's notice. The practical difficulties in carrying out this recommendation are insignificant in comparison with the importance of the results. With practice, five minutes usually suffices to effect a positive microscopical diagnosis of malaria.

Every tropical practitioner should be provided with a travelling microscope, or, at least, carry about with him a few microscope slips for blood films. He must be on his guard, however, against concluding from the discovery of malaria parasites in his films that malaria is necessarily the only, or even the principal, disease his patient is suffering from.

CHAPTER VIII

MALARIA: TREATMENT

Quinine.—Many drugs have been employed in the treatment of malarial disease, and many drugs have some influence on it; all sink into insignificance in comparison with quinine. In serious cases, to use any drug to the exclusion of quinine is culpable trifling. Therefore, so soon as a diagnosis of malaria has been arrived at, unless there be some very manifest contra-indication, the first duty of the practitioner is to set about giving quinine. There are many ways of exhibiting the drug; however given, care must be taken that it is so administered that there can be no mistake about its being absorbed. If the patient for any reason, such as inability to swallow or persistent vomiting, cannot take quinine by the mouth, and the existing condition be grave, it may be injected by the rectum; but if the circumstances of the case are such that neither of these channels for administration is available, and a rapid action of the drug is imperative, it must be injected at once intramuscularly, or into a vein.

When and in what dose to give quinine in ordinary cases.—During a paroxysm of ordinary intermittent fever it is better, before giving quinine, to wait until the rigor and hot stages are over and the patient is beginning to perspire. A fever fit, once begun, cannot be cut short by quinine, and to give quinine during the early stages aggravates the headache and general distress; but so soon as the skin is moist and the temperature begins to fall, the earlier the drug is commenced the better. Ten grains, preferably in solution, should be administered at the commencement of sweating, and thereafter 5 gr. every six or eight hours for the next week. This is an almost certain cure. The quinine may not always

prevent the next succeeding fit, but it nearly always diminishes its severity. In ninety-nine cases out of a hundred the second following attack does not develop.

When giving quinine it is well to administer an aperient and to keep the patient in bed; in ordinary cases neither aperient nor rest in bed is absolutely necessary. In cachectics, however, and in all obstinate cases, both are valuable adjuvants.

My practice in the treatment of ordinary malarial fevers is to give quinine for a week in the doses mentioned. At the same time, with a view to prevent recurrence of fever, I direct the patient, particularly if I have found the crescent form of the parasite in the blood—for such cases are specially prone to relapse—on one day a week (to give precision to my directions I generally mention Sunday) to take a mild saline, sulphate of soda or Carlsbad salts, in the morning, and three 5 gr. doses of quinine during the day, or 15 gr. in one dose. After the first week iron and arsenic in pill, tabloid, or solution are prescribed for a fortnight, and, after an interval of a week, for another fortnight. The weekly aperient and quinine had better be kept up for six weeks or two months or longer. In other cases I recommend, after the preliminary week, 5 gr. of quinine daily; this dose to be kept up for three months, and repeated for a month every spring and fall for two years.

Dose of quinine: toxic effects.—There is great difference of opinion and practice about the dose of quinine. Some give 30 gr. at a dose, some give 3 gr. The former, in my opinion, is too large a dose for ordinary cases, the latter too small. It must never be lost sight of that occasionally quinine in large doses produces alarming effects; not singing in the ears and visual disturbances merely, but actual deafness and even amblyopia, both of which may prove very persistent and occasionally permanent. It may also produce profound cardiac depression and gastric disturbance, and even death from syncope. Urticaria is another, and not very uncommon, effect

of even small doses of quinine; some cannot take it on this account, and prefer to endure the disease rather than suffer the intolerable irritation induced by the remedy. I believe that nothing is gained by excessive doses; in ordinary circumstances, 30 gr. spread over two or three days is usually ample to check an intermittent.

In the endemic area of hæmoglobinuric fever, and even in the case of individuals who have long left that endemic area, large doses of quinine do sometimes undoubtedly determine an explosion of that highly dangerous disease, especially so, but not exclusively so, in the cachectic. This important fact must not be lost sight of, and when there is any good reason to apprehend such a calamity, quinine should be given at first in ½-gr. or 1-gr. doses, gradually increased to 5 gr. or more three or four times a day.

For children under one year, ½ to 1 gr. for a dose suffices; for older children the dose must be increased proportionately to age and strength. Children tolerate the drug well, so that in serious cases—pernicious comatose or other cerebral forms—the drug should be vigorously pushed.

If a supposed ague resist the doses of quinine mentioned, the diagnosis should be revised.

Quinine in pregnancy.—Care should be exercised in giving quinine to pregnant females, for undoubtedly it sometimes causes miscarriage. The fact of pregnancy, however, must not debar the use of the drug altogether; only, in such circumstances, it should be given in the minimum dose likely to be effectual, say 3 gr. repeated every eight hours for two days. A pregnant woman will run more risk of miscarriage and of detriment to her health from repeated ague fits than from a reasonable dose of quinine.

Quinine in the puerperal state.—It is a wise precaution in malarious countries to give a few 5-gr. doses of quinine during labour or soon after. The puerperal state seems to have the effect, as any other shock or physiological strain might, of waking up the slumbering malaria parasite. A dose or two of quinine in these circumstances does no harm,

and may, by choking off a threatening fever, avert suffering and anxiety, not to mention danger.

Form in which to administer quinine.—Quinine is best given in solution, and probably the hydrochloride, as containing a larger proportion of the alkaloid than the sulphate, is the best salt. Some, under the impression that hydrobromic acid prevents the singing in the ears attending the free use of the drug, prefer this to dilute sulphuric acid as a solvent for the ordinary sulphate. When the tongue is fairly clean and digestion not altogether in abeyance, the quinine may be given in freshly prepared pill, in tabloid form, in cachet, or enclosed in cigarette paper; but in serious cases, particularly where the tongue is foul and digestion enfeebled, pills and tabloids are not to be trusted to. *In these circumstances they are apt to pass through the bowels and to appear in the bedpan unaltered.* In grave cases this occurrence must not be risked.

Euquinine or euchinine, the ethyl carbonate of quinine, *quinine tannate*, and *aristoquinine*—a diquinine carbonic ester—have the advantage of being almost tasteless, an important property in the case of fever in children or fanciful patients.

Milk as a menstruum for quinine.—If the taste of the ordinary salts of quinine be very much objected to, and if euquinine is not available, a good plan is to give quinine in powder in a tablespoonful of milk after the patient has previously lubricated the mouth with a morsel of bread and butter. Given in this way the bitter taste of the drug is not perceived.

Injection of quinine.—In any type of fever, if vomiting is persistent, if the brain is affected, or if the patient is insensible and cannot or will not swallow, recourse must be had to rectal or intramuscular injection of quinine. In all cases in which life is in imminent danger, and in which the earliest possible action of the drug is of importance, it must be so administered. The intramuscular method is sometimes a painful one, and may be attended with some risk of abscess; in the circumstances, such possibilities count for little.

The most suitable readily procurable salt for intramuscular injection is the hydrochloride, or, better, the bihydrochloride, which is soluble in less than its own weight of water. The hydrobromide is equally soluble. If neither of these salts can be procured the sulphate may be used, solution being effected by adding half its weight of tartaric acid.* Seven to 15 gr. dissolved in 30 to 60 min. of sterilized water would be a full dose; in grave cases this dose should be given three times in the twenty-four hours. The needle should be driven well home, deep into the muscles of the gluteal or scapular region, the skin being previously carefully cleansed. The solution must be freshly prepared and boiled, and the syringe and needle thoroughly sterilized. A syringe having a well-fitting glass piston and a plugging needle has recently been put on the market; this is the best instrument for giving these injections. In the malignant fevers of Rome as much as a drachm of quinine, divided into three or four doses, is sometimes administered intramuscularly in the course of twenty-four hours with the best results.†

* The more serviceable salts of quinine, of which the bichloride of quinine and urea is one of the best, can now be procured in tabloid form specially prepared for intramuscular injection. These tabloids are much better than solutions, which cannot be kept for any length of time without risk of fouling.

† SOLUBILITY AND EQUIVALENT VALUE OF SALTS OF QUININE.
Those marked by an asterisk are suitable for hypodermic injections.

Name of salt.	Percentage of the alkaloid in the salt.	Solubility in cold water.	Amount equivalent in value to one of quinine sulphate.
Sulphate	73·5 %	In 800 parts	1·00
Hydrochloride ...	81·8 %	,, 40 ,,	·9
*Bihydrochloride ...	72·0 %	,, 1 ,,	1·02
Hydrobromide ...	76·6 %	,, 45 ,,	·96
*Bihydrobromide ...	60·0 %	,, 7 ,,	1·23
Bisulphate	59·1 %	,, 11 ,,	1·24
Phosphate	76·2 %	,, 420 ,,	·96
Valerianate	73·0 %	,, 110 ,,	1·01
*Lactate	78·2 %	,, 10 ,,	·94
Salicylate	70·1 %	,, 225 ,,	1·05
*Hydrochloro-sulphate	74·3 %	,, 2 ,,	·99
Arseniate	69·4 %	slightly soluble	1·06
Tannate	20·0 %	,, ,,	3·67
*Bichl. of q. and urea			

The best place for a quinine injection is the gluteus maximus muscle at a point somewhere from 2 to 3 in. below the crest of the ilium. After the injection is made the part should be gently massaged so as to diffuse the solution, and the little wound sealed with collodion. Quinine ought never to be injected into the neighbourhood of large nerves or blood-vessels, and never into the subcutaneous connective tissue, as in the case of morphia and other alkaloids. I have long been in the habit of using intramuscular injections of quinine, both in hospital and in private practice, and, so far, without mishap. My belief is that abscess, indurations, and similar accidents are for the most part attributable to imperfect methods and carelessness.

Intramuscular injections of bihydrochloride of quinine, 7 to 10 gr. in 10 to 20 minims of water daily for a week, is the best way of checking obstinately relapsing malarial attacks.*

Precautions.—It may be well to mention—not with the idea of deterring the practitioner from using the drug in this way, but to impress upon him the necessity for sterilizing the patient's skin at the place selected for injection, and for care in keeping instruments and solutions aseptic—that not only abscess, sloughing, and chronic painful indurations have sometimes followed the hypodermic injection of quinine, but also tetanus. In these latter unfortunate cases it was not, of course, the quinine that directly caused the tetanus; it was the tetanus bacillus, and this tetanus bacillus was introduced either on a dirty needle or in a fouled solution. Further, as Semple has pointed out and emphasized, the tetanus bacillus may be present in the body without giving rise to symptoms, provided the vitality of the tissues is not seriously impaired by injury or irritant. Unlike morphia, or emetine, quinine is a powerful irritant, and, when

* Quinine when lodged in a muscle is not invariably immediately absorbed. It may be precipitated and thereafter slowly absorbed, thus ensuring the continuous presence of the drug in the blood. To this and to the consequent continuity of action on the parasite has been attributed the undoubted efficacy of this method of administering quinine in obstinate cases of malarial infection.

injected, may suffice to render the implicated area a suitable culture ground for the bacillus and the elaboration in lethal quantities of tetanus toxin.

Tetanus is an exceedingly common disease in some tropical countries. In Western Africa, for example, a large proportion of wounds, no matter how trifling as wounds they may be, if they are fouled by earth or dirt result in tetanus. The French in Senegambia have found this to their cost. A gentleman who had travelled much in Congoland told me that certain tribes poison their arrows by simply dipping the tips in a particular kind of mud. A wound from these arrows is nearly sure to cause tetanus. In many tropical countries, so general and so extensive is the distribution of the tetanus bacillus that trismus neonatorum is a principal cause of the excessive infant mortality. Every precaution must therefore be taken to ensure that the little instrument which is so potent in saving life may not by carelessness be turned into an instrument of death. The systematic use of tetanus antitoxin in quinine injection treatment has been advocated; but, it seems to me, this is hardly practicable under ordinary tropical conditions.

It is scarcely necessary to add that the intramuscular injection of quinine must not be practised without good reason, or as the routine treatment of ordinary malarial attacks.

Quinine by enema.—Quinine may also be given by enema. It is readily absorbed if the bowel be not too irritable. The dose should be a large one. Thirty gr. given in this way and repeated in an hour or two in malarial comatose fever has sometimes a rapid effect. It is the most effective method of exhibiting the drug in such attacks in children. Five gr. in warm solution, repeated hourly, retention being ensured by the attendant keeping the patient's buttocks together, is strongly recommended by Daniels.

Intravenous injection of quinine.—In cases of pernicious comatose remittent, in which it is of importance to obtain a rapid and powerful action of the drug, Bacelli recommends the intravenous injection

of the following solution: Hydrochloride of quinine 1 grm., sodium chloride 75 cg., distilled water 10 grm. This solution he has employed in these desperate cases with much success, injecting directly into a vein 5 to 7 grm. at a time. He states that whereas with hypodermic injection the mortality in such cases amounted to 17 per cent., with intravenous injection it was reduced to 6 per cent.

Warburg's tincture.—A very effective medium for giving quinine, and one of high repute in many places, is Warburg's tincture. This contains, besides quinine, a number of drugs, many of them doubtless inert, although some of them certainly possess valuable therapeutic properties. Experience has shown that the combination is really a good one, and that Warburg's tincture sometimes succeeds where quinine alone fails, or acts too slowly. It generally proves a powerful sudorific. The dose is ½ oz., and is repeated after two or three hours. The action appears to be somewhat similar to that of the antipyretics now in vogue—antipyrin, phenacetin, etc.—drugs which, when given in combination with quinine in the routine treatment of malarial fevers, although they have no curative properties, sometimes contribute very markedly to the relief of headache and febrile distress. They must be used with great caution in adynamic cases. At the present time these drugs are much abused in many malarial countries.

Mode of action of quinine.—In what way quinine acts has not yet been satisfactorily explained. Some, reasoning from the toxic influence this drug exerts on many kinds of free amœbæ, say that it acts in malaria in the same way—that is, as a direct poison to the parasite. They support this view by pointing to the degenerative changes, as evidenced by imperfect staining reaction, exhibited by such parasites as persist in the blood after administration of quinine has been commenced. Others maintain that it acts in stimulating the phagocytes, the natural enemies of the parasite. Some experimentalists allege, on the other hand, that it paralyses the white corpuscles.

Patients who have suffered from a hyperpyrexial attack should be invalided home.

Treatment of algide and dysenteric attacks. — Algide and dysenteric attacks demand quinine combined with a little opium. If dysenteric symptoms persist, emetine, or ipecacuanha, or the aperient sulphates in full doses, and opium, according to the nature of the dysentery, must also be given.

Other drugs in malaria.—During the continuation of a fever I have never seen much, if any, good from arsenic. The place of arsenic is not as a substitute for quinine during fever, but as a blood restorer after fever. I have heard of cases of obstinate ague cured by ½-drachm doses of liquor arsenicalis; I have never myself ventured on these heroic doses. Recent experiments show that although salvarsan and neo-salvarsan have some effect on the quartan and tertian parasites, they have little if any on the subtertian. A strong infusion of "the hairs that grow between the grain and the outer leaves of the mealie cob" (dose, 3 tablespoonfuls) has recently been recommended as a cure for malaria; I have no experience of it. I have never seen benefit, in any way approaching that derived from quinine, from methylene blue, carbolic acid, iodine, anarcotine, analgen, phenocol, parthenium, ailanthus, chiretta, eucalyptus, or any of the many drugs which from time to time have, on very limited experience, been recommended in malaria. In those cases, however, in which from some idiosyncrasy the patient is unable to take quinine, it may be necessary to have recourse to some of these drugs. Methylene blue in doses of 2 to 3 gr., and pushed until the urine becomes deeply tinged or signs of kidney irritation appear, enjoys a certain reputation in America and in Germany. Anarcotine was at one time, during a quinine famine, extensively and successfully employed in India; the dose is from 1 to 3 gr. Phenocol hydrochloride, in 10-gr. doses, administered five, three, and two hours before the expected paroxysm, has been used with advantage in Italy, and is said to have succeeded in some instances in which quinine

had failed. Tannin has been recommended in obstinate cases where quinine had failed or could not be taken. A grain of capsicum with 5 gr. of quinine is said to succeed sometimes where quinine alone fails. I have given this pill, but cannot determine how much the capsicum contributed to the cure. I cannot say I have ever seen an ordinary uncomplicated ague absolutely resist quinine properly given. I have seen cases of obstinately recurring ague apparently permanently cured by a few intramuscular injections of quinine, although the same drug, given in the ordinary way, had proved a comparative failure. There can be little doubt, however, that in rare cases it does fail, and that it is more efficient against the benign tertian and the quartan than against the malignant parasites. It does not always prevent relapse, even in the non-malignant infections.

Treatment of splenic tumour and malarial cachexia.—The enlarged spleen of malarial cachexia is best treated by counter-irritation (linimentum iodi, or ung. hydrarg. biniodid.) and saline aperients, combined with quinine, arsenic, and iron. Hepatic enlargement and abdominal congestion arising from malarial disease of long standing generally derive much benefit from a course of Harrogate, of Kissingen, of Carlsbad, or of other aperient mineral water. When these waters cannot be obtained, a morning aperient saline, kept up for two or three weeks, is an efficient substitute. Aperient courses should, as a rule, be combined with moderate doses of quinine, and be followed by courses of iron and arsenic. Cachectics should leave the malarial centre where they are being poisoned, and spend at least one year in Europe. They must be careful to clothe warmly, especially on first entering colder latitudes; to keep lightly employed both in body and mind; to avoid over-fatigue, constipation, exposure to a very hot sun, high winds, rain; to live temperately, and generally to follow the dictates of common sense. Residence in a dry, cool, sunny climate, or a sea-voyage, is an admirable restorative in malarial cachexia.

Malarial cachectics must exercise great caution about exposing themselves to the fresh sea breezes on the return voyage to Europe. Neglect of this is nearly sure to be punished with an attack of fever, sometimes of fatal blackwater fever. Many such fatalities occur yearly in cachectics from West Africa during the voyage to Europe. Return to Europe in the winter season should, if possible, be avoided, the colder months being spent in the Canaries, Egypt, or the Riviera. *If quinine is being taken when the patient leaves for Europe, its use, in the accustomed dose, should be systematically continued during the voyage and for several months, at least three, after arrival.* I find that malarial cachectics are often allowed to start on the voyage to Europe inadequately instructed on these important points.

Food and drink in malaria.—The food in malarial fevers ought to be light and principally fluid. Effervescing mixture often helps to clean the tongue and settle the stomach. Lemon decoction (made by boiling for half an hour a sliced lemon, including skin and seeds, in a pint and a half of water, straining, diluting, and sweetening) is much relished in remittents, and may be taken systematically by all malarials with advantage. Fresh lemonade, fresh lime juice, weak cold tea, and iced water sipped are all of them much appreciated by these patients. During convalescence the quality of the food should be gradually improved and, if necessary, supplemented by a light wine or bitter ale.

PROPHYLAXIS

The basis of malaria prophylaxis is the fact that particular species of mosquitoes are indispensable for the propagation of the parasites. Practical measures, therefore, have for their object the extermination of these insects, or, failing this, the prevention of their bites. War need not be waged against all mosquitoes; our present knowledge seems to indicate that only the Anophelinæ have to be considered. As the members of this sub-family are easily recognized (p. 146), and as they are somewhat fastidious in their habits, their

extermination in limited areas is by no means a hopeless task.

Drainage, cultivation, and flooding.—Experience has shown that much can be done to free a locality of malaria. Drainage and cultivation where the land will repay the expenditure, permanent and complete flooding where it will not and where such flooding is possible, proper paving and draining of unhealthy towns, and the filling-in of stagnant, swampy pools—these are the more important things to be striven for in attempting the permanent sanitation of malarious districts. In England, in Holland, in France, in Algeria, in America, and in many other places, enormous tracts of country which formerly were useless and pestilential have been rendered healthy and productive by such means.

In carrying out extensive public works care should be exercised to provide good subsoil drainage in connection with irrigation, to provide efficient drainage to carry off superfluous water *before* introducing a larger water supply into a town previously inadequately watered, and to avoid interfering with the natural drainage of a district in constructing railways and so forth. To do anything that may raise the level of the subsoil water in potentially malarial districts is most dangerous. Equally so is the neglect to fill up, or provide for the drainage of excavations, such as the "borrow-pits" in railway construction or similar holes in which rain-water may accumulate and create breeding pools for mosquitoes.

Location of dwelling-houses. — The inhabitants of malarious districts ought to live in villages or towns with well-paved streets and courts, going out to cultivate their fields during the day, but returning to sleep in the town before nightfall. Houses should be placed, if possible, on high and dry situations, a clay soil being avoided. All forest undergrowth should be cleared away. It is unwise in countries such as Africa, where nearly all Europeans suffer from chronic malarial poisoning, to place dwelling-houses in exposed situations, or where high winds are apt to produce chills and consequent fever relapses.

For the same reason, in elevated situations houses should be well sheltered by trees planted at some distance from the premises, or by higher ground. In the neighbourhood of houses the felting of natural grass should, if possible, be preserved, or, if it be disturbed, replaced immediately, or the exposed soil covered with rammed clay or cement. It is unwise to have flower-beds or vegetable gardens near bedroom windows, or to allow water from bath-rooms or cook-houses to flow over the ground in the vicinity of the house, or to keep water unchanged in tubs or water-butts for mosquitoes to breed in. Pools and puddles of stagnant water should be filled up and turfed. Ponds should be stocked with fish, as fish tend to keep down mosquitoes by preying on their larvæ. The neighbourhood of swamps is to be avoided. A few ounces of petroleum thrown on the surface of a pond will prevent mosquitoes from depositing their eggs on the water, and will asphyxiate their larvæ; the petroleum requires to be renewed from time to time—say once a week. Coal tar may be used in the same way. There are many simple precautions of this sort which will occur to every prudent man, and which, in malarious countries, he should take care to have carried out.

Danger from vicinity of natives.—Seeing that a large proportion of the native children harbour the malaria parasite, and that a large proportion of the anophelines in the neighbourhood of native houses are infected, it is manifest that to visit native quarters when mosquitoes are feeding, especially in the evening or during the night, is fraught with danger. For the same reason the European should build his house or pitch his camp well away from native quarters, and beyond the flight of infected anophelines ; and, for the same reason, native children should not be allowed to frequent European establishments.

The cultivation of trees and plants.—Much was expected at one time from the cultivation of eucalypti of different species—particularly *Eucalyptus globulus*—as a means of suppressing malaria. Specific virtues were attributed to its balsamic exhal-

ations. These hopes have not been fulfilled in every case; but, undoubtedly, the effect of this rapidly-growing tree in drying the soil is of use in some localities. The same may be said of the cultivation of the sunflower, chrysanthemum, kiri tree, and other plants. Possibly these plants influence insect life in other ways.

Native experience to be consulted.—It unwise to build where the natives say the neighbourhood is unhealthy; natives generally know such places. Neither, if it can be avoided, should a stay be made where the natives are anæmic and have enlarged spleens—sure indications of an unhealthy district.

Other precautions.—Bedrooms should be situated in an upper storey, and dwelling-rooms be well raised on piles or arches above the ground. Common sense tells us that campaigns and journeys in malarious districts should be conducted and concluded during the healthy season, if there be one. *Mosquito nets must invariably be used;* many travellers attest their value, so plainly indicated by recent discoveries. The body should be covered up during sleep, and every precaution (as fires, etc.) that circumstances permit should be employed to keep mosquitoes away.

The subjects of malarial infection are dangerous to their companions; they should, therefore, be avoided or, if this is impracticable, compelled to sleep under efficient mosquito nets. Mosquitoes must be rigorously excluded from hospitals. It will prove a truly economical procedure to supply natives liberally with quinine; this should go hand in hand with other steps that may be taken to render a place salubrious.

Mosquito-protected houses.—It has been proved experimentally and practically that complete protection from mosquito bite, and therefore from malaria, can be secured by having the dwelling-house protected by gauze fittings, with a mesh not larger than twelve strands to the inch, in the doors, windows, chimneys, and ventilators. When possible, such measures should be adopted and intelligently applied. I believe some such arrangement will, in the ne

future, be a feature in the domestic architecture of malarial countries.

Quinine and arsenic as prophylactics.—A great deal has been written about the prophylactic use of arsenic and quinine in malaria. Opinions are very much divided on the subject. Most deny that arsenic possesses any prophylactic power whatever. Duncan, after an exhaustive study of the recorded evidence, and after extensive and carefully conducted experiments made by himself on large bodies of troops, concludes that arsenic has no prophylactic virtue whatever; but that quinine, in a daily dose of 3 to 5 gr., lessens the fever admissions by one-half. He therefore strongly advocates the systematic use of the latter drug in all campaigns involving a sojourn in malarious districts. In this he is backed by the opinion of many medical men of experience. Corre, although he admits the prophylactic power of quinine against ordinary malarial fever, says it has no influence in preventing pernicious fevers. Other authorities, on the contrary, state that those who take quinine systematically, though liable to mild fevers to some extent, enjoy immunity from pernicious attacks. On the whole, the evidence is distinctly in favour of the systematic employment of a dose of quinine as a prophylactic.

There is considerable difference of opinion and practice as to the dose and the time of administration of quinine. There are three principal methods: (*a*) 5 gr. every day after breakfast, (*b*) 10 gr. twice a week, (*c*) 15 gr. every tenth and eleventh day. Some prefer one method, others another; when one plan proves unsatisfactory another should be tried. If for any reason quinine is not tolerated, that individual is unsuitable for residence in malarial countries.

Other prophylactics.—Tea, coffee, and very small doses of alcohol are also decidedly of service; but they should be used in strict moderation, the last being taken only after the work of the day is over, and when there is no longer any necessity for going out in the sun. Crudeli speaks highly of lemon decoction (made as already described, p. 130) as a

prophylactic; its use can do no harm, and it is a pleasant, slightly tonic, and slightly aperient beverage, well suited as a drink in hot climates. The decoction made from one lemon may be taken daily in divided doses.

Education.—It is impossible to lay down directions for the prevention or suppression of malaria which would be applicable at all times and to all places, and under every circumstance. What might suit one set of conditions might not be appropriate under other conditions. But by one, or other, or all of the measures indicated above, much can be done to mitigate or avoid endemic malaria. Perhaps the most important initial measure in the struggle with the pestilence is the education of the inhabitants of malarial countries in the mosquito-malaria theory. Sanitary measures can rarely be carried out effectually without the co-operation of those whom they are intended to benefit; and this co-operation cannot be secured unless the rationale of their operation is understood. Therefore, those responsible for the public health in malarial districts should, by one means or another, indoctrinate the people in the mosquito-malaria theory. If he succeed in this, the sanitarian will have an easier and a more hopeful task.

CHAPTER IX

MALARIA: THE MOSQUITO

THE part played by the female mosquito, or gnat, in the life-history of the germ of malaria, as well as in that of yellow fever, of filariasis, and, most probably, of dengue and perhaps other diseases of warm climates, renders some knowledge of the natural history of this insect a necessity for the tropical pathologist.

Although the Culicidæ or mosquitoes had received, now and again, some attention from naturalists ever since the time of Linnæus, it is but recently that the extent, complexity, and importance of this group of insects have been apprehended. Considerations of space preclude me from giving more than the merest outline of the subject; those who desire to follow it up would do well to provide themselves with one, or more, of four recent works—namely, Alcock's "Entomology for Medical Officers," Theobald's "Monograph of the Culicidæ," Blanchard's "Les Moustiques," Giles's "Handbook of the Gnats or Mosquitoes," in which will be found details of all that was known about these insects up to the date of their publication.

The **Culicidæ**, of which there are at least 500 known and, probably, over 200 additional and as yet undescribed species, belong to the order of Diptera, or two-winged insects, in which the posterior of the two pairs of wings of the typical insect are rudimentary, being represented by the *halteres* or balancers (Fig. 23). Like the other members of the order, they lay *eggs*, from which are hatched worm-like *larvæ*; these, after growth and several changes of skin, cease to eat, and become converted into *nymphs* or *pupæ*, from which, by a rupture of the pupa-case, the adult insects or *imagines* emerge.

The geographical range of the mosquito extends

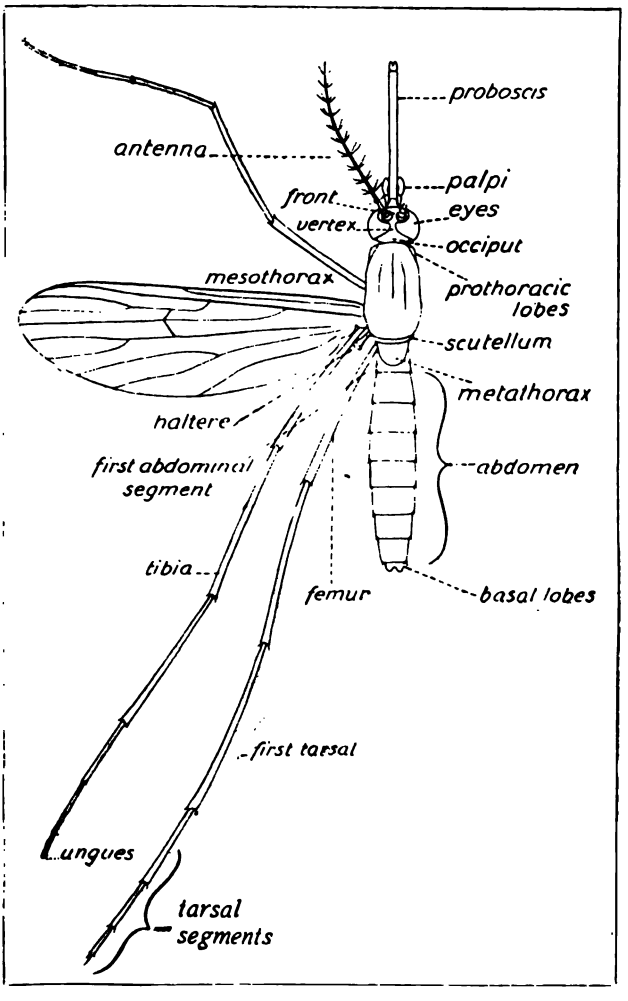


Fig. 23.—Female mosquito

from the frigid zones to the equator. Given stagnant or slow-flowing water and a summer temperature, there this family of insects will be represented by one or many species. The distribution of particular species and the abundance of mosquitoes in any given place are determined, in addition to temperature and hydraulic conditions, by complicated circumstances not yet wholly understood.

The adult insect feeds on vegetable juices; the males, with few exceptions, exclusively so. In addition to a vegetable diet, the females of most species, when opportunity offers, suck the blood of mammals, birds, occasionally of fishes, reptiles, and

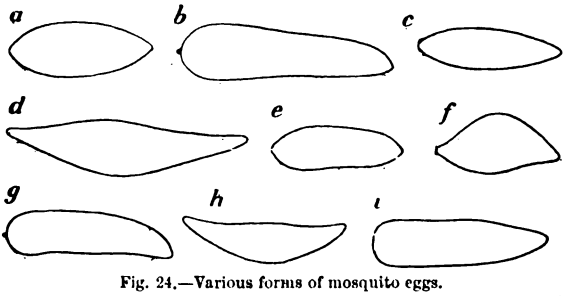


Fig. 24.—Various forms of mosquito eggs.

a, Grabhamia dorsalis; *b*, Culex pipiens; *c*, Culex scapularis; *d*, Mansonia titillans; *e*, Stegomyia calopus (fasciata); *f*, Tæniorhynchus fulvus; *g*, Culex fatigans; *h*, Ianthinosoma mexicanum; *i*, Tæniorhynchus fasciolatus.

even that of other insects and their larvæ. The male mosquito, not being a blood sucker, takes no part in the diffusion of disease; it is the female only that is a germ carrier.

Soon after impregnation the female lays her eggs (Figs. 24, 25, 26) from time to time—singly, in groups, or in boat-shaped masses, according to species—on the surface of still water, on which they float. The process of hatching out depends in great measure, as indeed do all the developmental processes connected with the mosquito, on temperature, being retarded or even suspended by cold and accelerated by warmth. At ordinary summer temperature the larvæ hatch out in from two to three days, and at once proceed to feed voraciously on the organic materials

suspended in the water. Being air-breathers, a great part of their time is passed at the surface of the water, where they lie in such a position—which varies with species—that the respiratory opening placed near the tail can function readily (Figs. 27, 28). After the several moultings the larva, now very much increased in size, passes to the nymph or pupa phase (Fig. 29), during which the little animal ceases to feed, and for the most part floats just awash at the surface of the water. In from one to two days the pupa-case bursts and the insect, emerging, stands on the empty case till its wings have dried, when it flies away. From first to last, from egg to imago, the process of development takes about a month in the

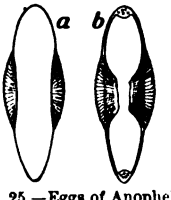


Fig. 25.—Eggs of Anopheles maculipennis.
a, Under side; *b*, upper side.

Fig. 26.—Culex pipiens—egg-boat. (*After Sambon.*)

temperature of the Italian summer; but a much shorter time (seven to ten days) may suffice in a tropical climate. As each female mosquito may lay eggs many times in a season, and many hundreds of eggs each time, and as the young female can produce eggs within a week or ten days after her emergence from the pupa-case, it follows that one pair of insects can give rise to several millions of their kind in the course of a summer.

During cold weather the development of the larva is temporarily suspended, and the surviving adults, at all events the females, hibernate in dark and sheltered places, to become active again on the return of warm weather. In this way the species is carried over the cold weather of winter. The duration of the life of the adult insect has not been definitely ascertained; it is known that some species, if supplied

with water and suitable food, can live for several months.

It is suggested that the mosquito tends to return to the particular pool in which she herself was hatched

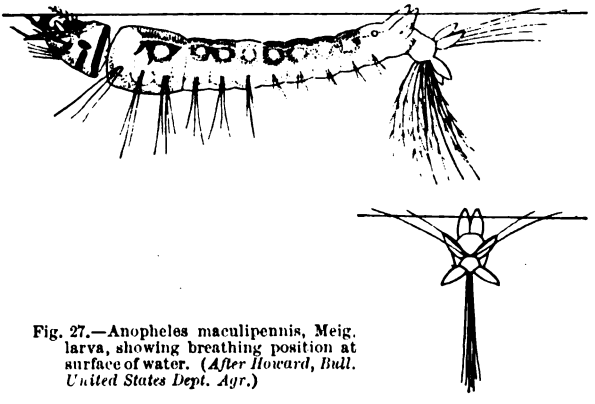


Fig. 27.—Anopheles maculipennis, Meig. larva, showing breathing position at surface of water. (*After Howard, Bull. United States Dept. Agr.*)

out to deposit her own eggs, and that she rarely strays from the vicinity more than a few yards, quite exceptionally beyond half a mile. Occa-

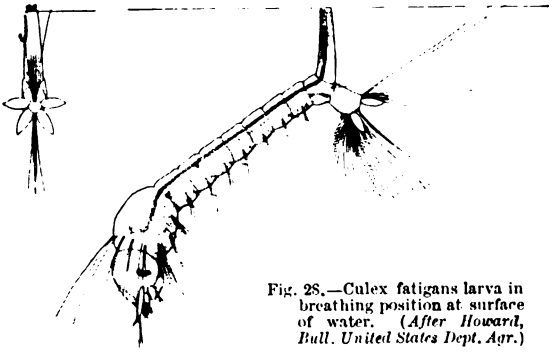


Fig. 28.—Culex fatigans larva in breathing position at surface of water. (*After Howard, Bull. United States Dept. Agr.*)

sionally she may be blown for some distance by gentle winds; and it is believed that in certain circumstances, probably connected with food supply and over-stocking, she will travel singly or in vast

swarms for long distances. Such migrations, however, are quite unusual. Of course, mosquitoes may be, and often are, transported great distances in ships, railway carriages, and similar vehicles, and in this way man aids in their diffusion; but for the most part the mosquito is a feeble and timid flyer, disliking to leave her accustomed haunt, and seldom rising high above the ground. So soon as even a moderate breeze springs up she seeks shelter in bush, or house, or cranny. Some species are domestic; others live exclusively in jungle or forest; some, after passing the day in the open, visit human habitations, or the haunts of birds and beasts, during the night. The

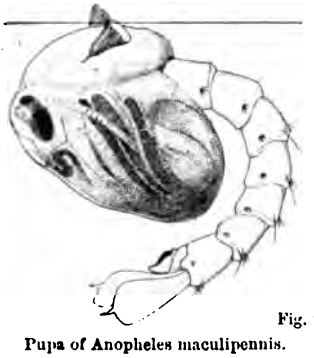


Fig. 29.

Pupa of Anopheles maculipennis. Pupa of Culex fatigans.

great majority of species are nocturnal in habit, although many of these can be coaxed into activity by the reproduction of night-like conditions of shade and atmospheric stillness.

The accompanying figures (Figs. 23–39) give a good idea of the leading features of the anatomy of the mosquito and of the names applied to the various parts and organs, and will help the student to understand descriptions of genera and species.

The antennæ of the male insect (Figs. 30, *a*, and 31, *c*) are adorned with a profusion of long, silky hairs, in marked contrast to the scanty, down-like, and short hairs on the antennæ of the female; this is an easily recognized indication of sex.

The proboscis consists of a number of piercing elements enclosed in a sheath—the labium, which, at

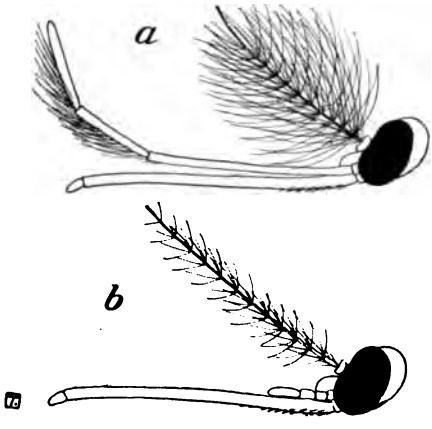


Fig. 30.—Heads of Culicinæ.
a, Male *b*, female.

its free end, is tipped with two minute labella. In feeding, the mosquito raises her hind legs and presses the tip of the proboscis against the skin. This

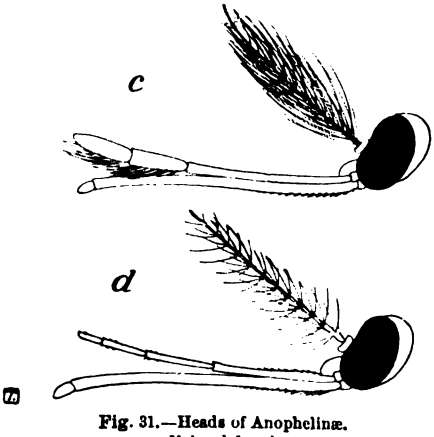


Fig. 31.—Heads of Anophelinæ.
c, Male: *d*, female.

causes the labella (Fig. 32, *h*) to splay out and so serve as a support to the piercing elements—namely, the labrum, hypopharynx, mandibles, and maxillæ (Figs. 32, 33)—which are now thrust into the skin. The labium does not penetrate; as the stabbing elements sink into the skin it bends backwards about its middle, the labella still pressing against the skin and clasping the stilettes. The secretion of the salivary glands (Figs. 11, 14) passes along the salivary duct and thence down a minute canal which traverses the hypopharynx to its tip, and so into the subcutaneous tissues of the bitten animal. It is supposed

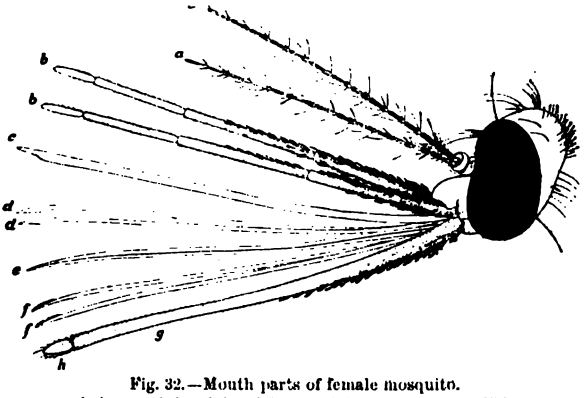


Fig. 32.—Mouth parts of female mosquito.
a, *a*, Antennæ; *b*, *b*, palpi; *c*, labrum-epipharynx; *d*, *d*, mandibles *e*, hypopharynx; *f*, *f*, maxillæ; *g*, labium; *h*, labella.

that the function of this secretion is, by irritating, to determine a flow of blood to the part bitten, and also to prevent coagulation of the blood. To many people this secretion is a powerful irritant, although repeated inoculation tends to produce tolerance, as in the case of many other organic poisons.

A buccal tube is formed by the apposition of the upper surface of the hypopharynx to the under surface of the labrum (Fig. 33). Along the tube so formed the blood is aspirated by the expansion of the gizzard-like organ (Fig. 11, *b*), and then driven by the contraction of the same into the stomach

(Fig. 11), or middle intestine, as it is called. A mosquito will fill herself in a minute or thereabouts. She then withdraws her proboscis and flies heavily away to some sheltered spot to digest the meal. Apparently the first step in digestion is the concentration of the blood she has imbibed; this is effected by excretion of the watery portion of the liquor sanguinis. Often while this process of dehydration is proceeding, even while she is sucking, droplets of clear fluid may be seen ejected at her anus. The concentrated blood becomes in this way a viscid tarry mass, which is gradually, in the course of three or four days, partly absorbed and partly voided as gamboge-coloured fæces. The mosquito is now ready for another meal. The rich pabulum supplied by blood seems to favour ovulation.

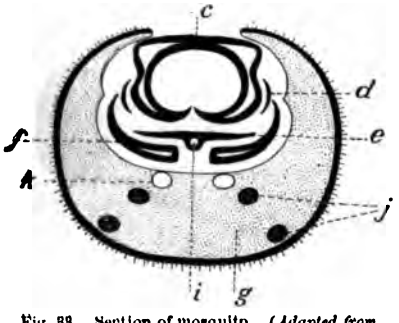


Fig. 33.—Section of mosquito. (*Adapted from Nuttall and Shipley.*)
c, Labrum-epipharynx; *d*, mandible; *e*, hypopharynx; *f*, maxillæ; *g*, labium; *i*, salivary duct; *j*, muscles; *k*, trachea.

Diagnosis.—Many kinds of insects possess blood-sucking propensities. As a rule there is little difficulty in distinguishing most of these from the mosquito. There are certain Diptera, however, which closely resemble the latter in appearance as well as in habit. These the student should learn to distinguish.

The principal of the mosquito-like blood-suckers are the Midges (Cheironomidæ) and the Sandflies (Phlebotomus). The following are the diagnostic points:—

Mosquitoes have a long suctorial proboscis, and the veins of their wings are fringed with scales.

Midges are very slender and minute, have a short

suctorial apparatus, and narrow wings without scales.

Sandflies are small, slender, and very shaggy, have a comparatively short suctorial apparatus, comparatively long legs, narrow hairy wings, and long hairy antennæ.

The medical man should be able not only to recognize mosquitoes but also to determine genera and species. Obviously, it would be impossible to give here minute descriptions of the vast number of species that have been described. Moreover, the classification of these insects is still very unsatisfactory. I must, therefore, refer the reader to the monographs

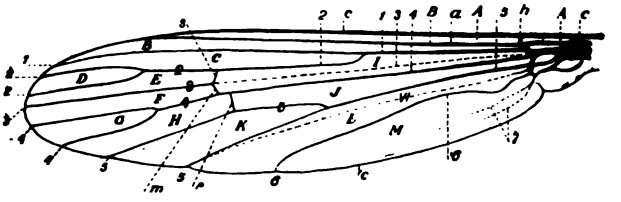


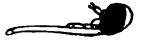
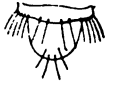
Fig. 34.—Wing of Culex concolor (male), to illustrate terminology.

c, Costa; *a*, auxiliary vein; *1–6*, first to sixth longitudinal veins and branches; *7*, seventh or false (unscaled) longitudinal vein; *VI*, unscaled vein between fifth and sixth longitudinal veins; *h*, humeral transverse vein; *s*, supernumerary transverse vein; *m*, middle transverse vein; *p*, posterior transverse vein; *A*, costal cells; *B*, subcostal cells; *C*, marginal cell; *D*, anterior fork cell or first submarginal cell; *E*, second submarginal cell; *F*, first posterior cell; *G*, hinder fork or second posterior cell; *H*, third posterior cell; *I*, first basal cell; *J*, second basal cell; *K*, anal cell; *L*, axillary cell; *M*, spurious cell

on the subject already mentioned. On the next page I give a **synoptical table** which will enable the student to identify the main groups or sub-families to which any given mosquito belongs. It has been prepared after a careful consideration of the various classifications proposed. This table is followed by Theobald's classification of the Anophelinæ, to which group, so far as we know at present, the malaria-bearing mosquitoes are restricted.

Theobald divides the Anophelinæ into eighteen genera, distinguished by the shape and arrangement of the scales. (Figs. 35–7.) I will not discuss the value of this classification, but I must remark that many authorities regard the characters given by

FAMILY CULICIDÆ *—CLASSIFICATION OF SUB-FAMILIES

- *Proboscis.*
  - Straight
    - 
    - *Metanotum.*
      - Nude
        -
        - *Palpi.*
          - Long in ♀ and ♂ — *Scutellum* simple, never trilobed — *Anophelinæ* (1), Theobald.
          - Short in ♀ and ♂
            - *Wings.*
              - 1st sub-marginal cell equal to or longer than 2nd posterior cell . *Ædinæ* (2), Theobald.
              - 1st sub-marginal cell shorter than 2nd posterior cell. Both very small *Uranotaeninæ*, Mitchell.
          - Short in ♀ long in ♂
            - *Wings.*
              - Six long scaled veins . . . *Culicinæ* (3), Theobald.
              - Seven long scaled veins . . . *Heptaphlebomyinæ*, Theobald.
      - With scales or hairs
        -
        - 
        - *Palpi.*
          - Short in ♀ and ♂ . . . . . *Dendromyinæ*, Lutz.
          - Short in ♀ long in ♂ . . . . . *Joblotinæ* (4), Blanchard
  - Recurved
    -
    - *Palpi* long in ♂; long or short in ♀ . . . . . *Megarhininæ* (5), Theobald

---

* The *Corethrinæ*, hitherto included in this family, were separated and raised to the rank of a family (*Corethriæ*) by Enderlein in 1905. They differ greatly from the *Culicidæ* by the structure of the mouth, which is not formed for piercing, by the absence of scales on wings, and many other peculiarities.

Synonyma.—(1) *Anophelina*, Theobald. (2) *Ædeimyina*, Theobald. (3) *Culicina*, Theobald. (4) *Trichoprosoponinæ*, Theobald, *Hyloconopinæ*, Lutz (5) *Lynchinellinæ*, Lahille.

OTHER SUB-FAMILIES PROPOSED.—Mitchell proposes the formation of a new sub-family *Deinoceratinæ*, to include *Ædinæ*, with very long second antennal joints. Theobald suggests a new sub-family *Limatinæ* for those *Dendromyinæ* in which the males have a jointed proboscis bent above the middle of its course. Christophers proposes to raise the genus *Stegomyia*, belonging to the Culicinæ, to the rank of a sub-family.

GENERIC CLASSIFICATION OF SUB-FAMILY ANOPHELINÆ, ADAPTED FROM THEOBALD

- *First sub-marginal cell of wing.*
  - Large
    - *Joints of antennæ.*
      - With many dense scale tufts . . . . . *Chagasia.*
      - Without dense lateral scale tufts
        - *Thorax* / *Abdomen* — Hair-like curved scales
          - *Head scales.*
            - Upright forked
              - *Basal lobe of gonostylus.*
                - 1 Segment
                  - *Wing scales.*
                - Large, lanceolate . . . *Anopheles.*
                - Mostly small, long, and narrow, or slightly lanceolate . *Myzomyia.*
                - Large, inflated, and disposed in patches . . . *Cycloleppteron.*
                - 2 Segments — *Prothoracic lobes* with dense outstanding scales . *Feltinella.*
            - Some flat in median area — *Prothoracic lobes* mammillated. *Wing scales* lanceolate . . . . . *Stethomyia.*
        - *Thorax* — With narrow curved scales; *Abdomen*—Hairy
          - *Head scales*
            - Normal, forked. *Wing scales* small lanceolate . . . . *Pyretophorus.*
            - Broad, not closely oppressed, but not forked or fimbriated. *Wing scales* broad, lanceolate . . . . . *Myzorhynchella.*
        - *Thorax* —Hair-like curved scales—some narrow curved scales in front; *Abdomen*—Hairy on dorsal surface—scaly on venter—prominent apical lateral scale tufts—no ventral tuft; *Wings* —Scales lanceolate . . . *Arribalzagia.*
        - *Thorax* —Hair-like curved scales; *Abdomen*—No lateral tufts—a distinct apical tuft — *Palpi* densely scaly. *Wings* with dense large lanceolate scales . . . *Myzorhynchus.*
        - *Thorax* —Hair-like curved scales and some narrow-curved lateral ones; *Abdomen*—Hairy with dense hair-like lateral apical scaly tufts; *Wings* —With scales short, dense, lanceolate. *Fork cells* short . . . . . *Christya.*
        - *Thorax* —Very long hair-like curved scales; *Abdomen*—Hairy, last two segments scaly — *Wings* with broadish, blunt, lanceolate scales. *Hind femora* with dense scale tufts . . . *Lophoscelomyia.*
        - *Thorax* —Narrow-curved and spindle-shaped scales; *Abdomen*—Lateral tufts and small dorsal patches of flat scales . . . . . *Nyssorhynchus.*
        - *Thorax* —Flat spindle-shaped scales
          - *Abdomen*
            - Nearly completely covered with scales irregularly disposed on dorsum
              - With dense lateral tufts . *Cellia.*
              - No lateral scale tufts . *Neocellia.*
            - Completely covered with large, flat, overlapping scales . . *Aldrichia.*
        - *Thorax* —Scales hair-like except a few narrow-curved ones in front; *Abdomen*—Long, broad, irregular scales . . . . *Kerteszia.*
  - Very small . . . . . *Bironella.*

Theobald as somewhat indefinite and difficult to interpret; moreover, variations may be met with in

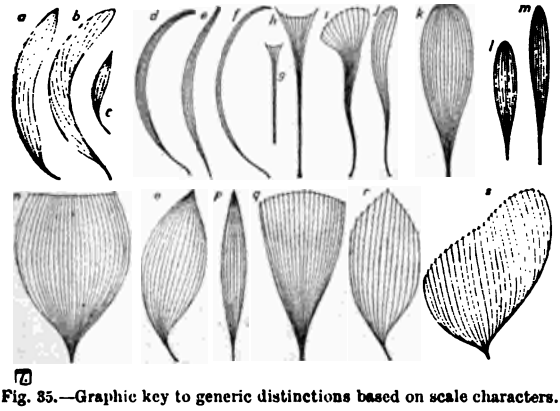


Fig. 35.—Graphic key to generic distinctions based on scale characters.

a, b, c, Narrow-curved scales; *d, e, f*, hair-like curved scales; *g, h*, upright forked scales; *i, j*, long twisted scales; *k*, large lanceolate scale; *l, m*, small narrow lanceolate scales; *n*, large inflated scale; *o, p*, spindle-shaped scales; *q*, broad flat scale; *r, s*, broad irregular scales.

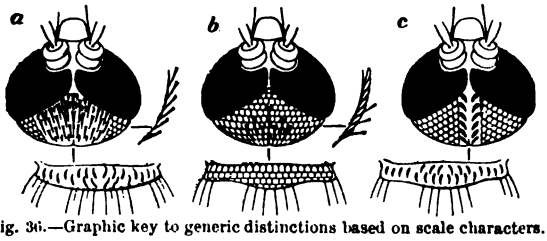


Fig. 36.—Graphic key to generic distinctions based on scale characters.

a, Anopheles, head, scutellum and lateral view of head scales; *b*, Stegomyia, head, scutellum and lateral view of head scales; *c*, Ædes, head and scutellum scales.

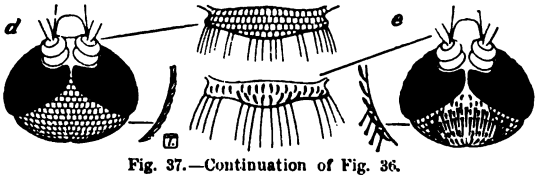


Fig. 37.—Continuation of Fig. 36.

Megarhinus, head, scutellum and lateral view of head scales; *e*, Culex, head, scutellum and lateral view of head scales.

the shape and arrangement of the scales—the feature relied on—of any given species. On the other hand, classifications based on the venation of the wings, the structure of the ungues, the shape of the male genitalia, or the larval characters, have their disadvantages. Wing venation is often variable; the structure of the ungues has proved of little value; a classification based on larval characters is of no use in the determination of adult specimens. One based on male genitalia is also very unsatisfactory, because female specimens are far more abundant and of greater importance. Besides, of some genera we only know the female sex, and years may elapse before we find the corresponding male. A practical classification must necessarily take advantage of various characters, and these must be chiefly adult characters common to both sexes.

Species which have been found to foster the malaria parasites.—Of the large number of described species of Anophelinæ, the following have been shown, with more or less precision, to be efficient hosts of the malaria parasites :—

AFRICA.—*Myzomyia funesta, Pyretophorus costalis* and var. *paludis, Myzorhynchus mauritianus.* (Doubtful : *Cellia pharoensis.*)

EUROPE.—*Anopheles maculipennis, A. bifurcatus, Myzorhynchus sinensis.* (Doubtful : *Myzomyia superpicta, Myzorhynchus pseudopictus.*)

NORTH AMERICA.—*Anopheles maculipennis, A. crucians.* (Doubtful : *A. punctipennis, Cellia argyrotarsis.*)

SOUTH AMERICA. — *Anopheles pseudopunctipennis, Arribalzagia intermedius, A. pseudomaculipes, Cellia argyrotarsis, N. albimanus, Myzomyia lutzi.*)

AUSTRALIA.—*Nyssorhynchus annulipes.*

INDIA.—*Myzomyia culicifacies, M. ludlowi,* M. turkhudi, M. albirostris, M. listoni, Myzorhynchus*

* This species has recently been shown by Christophers to be the transmitter of a peculiarly localized malaria in the Andaman Islands. It breeds only in brackish water, and is not found farther away from such water than half a mile.

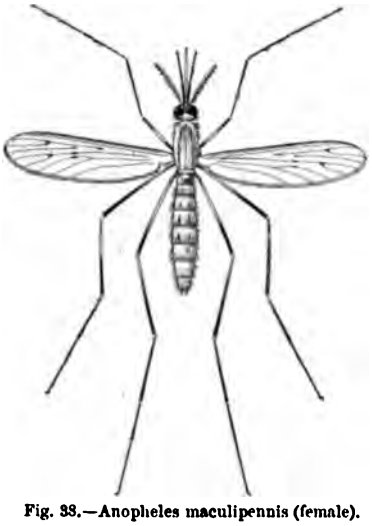


Fig. 38.—Anopheles maculipennis (female).

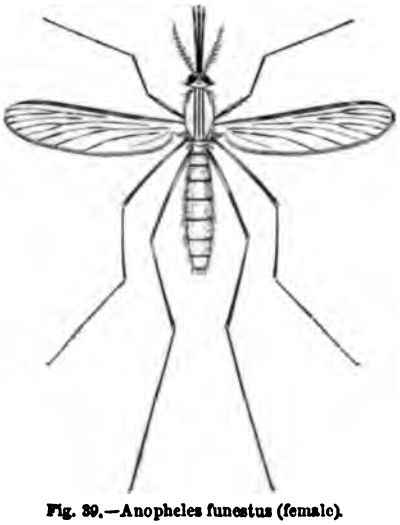


Fig. 39.—Anopheles funestus (female).

umbrosus, M. sinensis, Nyssorhynchus fuliginosus, N. willmorii, N. maculatus, N. maculipalpis, N. stephensi. (Doubtful: *M. rossii, M. christophersi, Pyretophorus jeyporensis, Myzorhynchus barbirostris, Nyssorhynchus theobaldi.*)

JAPAN. — *Anopheles formosaensis, A. cohacsus, Myzorhynchus sinensis.*

CAMBODIA.—*Anopheles martini, A. pursati.*
TONQUIN.—*Anopheles vincenti.*
MADAGASCAR.—*Myzorhynchus coustani.*
CELEBES.—*Anopheles vagus.*
NEW GUINEA.—*Cellia punctata.*
NEW HEBRIDES.—*Anopheles farauti.*
} Doubtful.

Fig. 40. — Resting position of Culex pipiens.

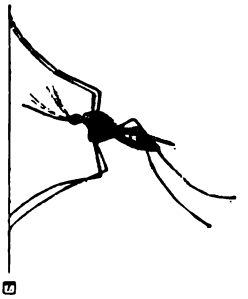


Fig. 41.—Resting position of Myzorhynchus pseudopictus.

Fig. 42. — Resting position of Anopheles maculipennis.

Whether other Anophelinæ are efficient has not been determined. So far no other Culicidæ have been found to foster the malaria parasites of man, and experiments with *Culex albopunctatus, C. penicillaris, C. vexans, C. pulchritarsis, C. pipiens, Taniorhynchus richiardii, Theobaldinella annulata,* and *T. nemorosa* have proved negative. Considering that *Culex pipiens* transmits several Hæmoprotozoa of birds, closely allied to those of men, it would be rash to assert positively that the Anophelinæ are the only mosquitoes which transmit the malaria parasite.

CHAPTER X

TRYPANOSOMIASIS OF MAN*

Definition.—Morbid conditions produced by *Trypanosoma gambiense*, including irregular chronic fever, skin eruptions, local œdema, adenitis, physical and mental lethargy, and, in a large proportion of cases, death.

History.—Although its true etiology was not apprehended until quite recently, sleeping sickness, the terminal phase of trypanosomiasis, has been known for over a century.

The occurrence of trypanosomes in animals has been recognized for at least sixty years, first in cold-blooded vertebrates, later in mammals. The best-known and first-described mammalian species is that of the rat (*Trypanosoma lewisi*). It was discovered by Lewis, in 1879, in Calcutta. In the following year Evans described a similar parasite (*T. evansi*) in the blood of horses in India; he found that it also infests camels, elephants, buffaloes, and dogs, and that it is the cause of the disease called surra, which, from time immemorial, the natives of India have ascribed to the bite of certain blood-sucking flies. Fifteen years later Bruce showed that nagana, the fly disease of horses, bovines, and other species of domestic mammals in Africa, is due to the same kind of organism (*T. brucei*). Since these discoveries were made trypanosomes have been found in many species of mammals, as well as in numerous birds, fishes, and reptiles. Though differing in degree of virulence, they all, at least in mammals, give rise to a more or less similar type of disease.†

* Laveran and Mesnil in their "Trypanosomes et Trypanosomiases, 1912," have given a very complete and accurate account of this subject. For full details up to date of publication the student is referred to this work.

† For a brief description of the trypanosomes of mammals the reader is referred to p. 190.

In 1890 Nepveu, in the course of researches in Algeria on malaria, encountered these flagellates in the blood of man. He appears to have been the first to do so; but, unfortunately, his original description is vague, and his illustrations are crude. He established no definite relationship between the organisms he alluded to and the associated morbid conditions; consequently, his observations did not receive the attention their significance deserved, although, later, he emphatically affirmed that a trypanosome has to be reckoned with as a factor in human tropical pathology.

In 1901 Forde encountered a flagellated parasite in the blood of a European suffering from an irregular non-malarial fever, in the River Gambia Colony. This parasite he showed to Dutton (1902), who recognized it to be a trypanosome. Later, Dutton found a similar organism in the blood of a native of the same colony, and suggested the name *T. gambiense*, which the parasite now bears. Subsequently many cases were described, both in Europeans and natives, and the association of the parasite with a peculiar form of febrile cachexia was quickly and satisfactorily established.

A great impulse was given to the study of the subject by the discovery of trypanosomes in the cerebro-spinal fluid, as well as in the blood of cases of sleeping sickness, by Castellani in Uganda in 1902. Castellani's suggestion that the parasite is the cause of sleeping sickness has been fully confirmed by Bruce, Nabarro, and other investigators, who have also shown that in Uganda the tse-tse fly, *Glossina palpalis*, is the transmitter of the infection, an hypothesis already advanced on analogical and epidemiological grounds by Sambon and Brumpt. Then (1909) came the important discovery by Kleine that the tse-tse fly was no mere mechanical transmitter of the trypanosome, as had been supposed, but was a true intermediate host. Later, on morphological and clinical grounds, Stephens and Fantham established the existence in Rhodesia of another species or variety of trypanosome (*T. rhodesiense*), which

Kinghorn and Yorke have since proved to be transmitted by *Glossina morsitans*.

Meanwhile Chagas had associated a disease, occurring in Brazil, with a peculiar species of trypanosome, *Schizotrypanum cruzi*, having a special transmitter, *Lamus* (*Conorhinus*) *megistus*. (*See* p. 185.)

Geographical distribution. — The presence of *T. gambiense* has been definitely ascertained for the west of Africa from the Senegal in the north to Mossamedes and the upper reaches of the Lualaba in the south. Also in the Niger and Congo basins, and in Uganda, where it must have been introduced only recently, apparently about the end of the nineteenth century. Throughout this vast area the infection is not uniformly distributed. It occurs

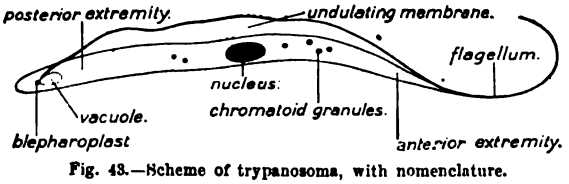


Fig. 43.—Scheme of trypanosoma, with nomenclature.

in a patchy way, principally along the banks of the rivers and shores of the lakes, conformably to the distribution of certain tse-tse flies, and apparently being influenced also by the frequency and nature of the intercourse and by the occupations of the inhabitants. There is strong reason for believing that the recent influx of Europeans into tropical Africa and the consequent increased movement of the natives is spreading the disease, and that this extension has by no means reached its limit. As regards the eastern side of the continent, the disease has not extended beyond the shores of the Victoria Nyanza. In this locality its present limits are Wadelai on the Nile to the north, and the southern end of Lake Tanganyika to the south. There is every reason to apprehend that, in time, the distribution of trypanosomiasis will become coextensive with that of the appropriate tse-tse flies.

Etiology.—In common with other trypanosomes, *T. gambiense*, as seen in fresh blood, is an active, wriggling organism, having a spindle-shaped body, which is slightly compressed laterally. It is provided with a delicate, wavy membrane—the *undulating membrane*—which fringes the convex dorsal edge of the body, and terminates in a free, whip-like filament, the *flagellum*. Suitably stained specimens show a *nucleus* about the centre of the body, and a minute, deeply staining chromatin mass, the *blepharoplast* (kinetonucleus), generally near one pole. The extremity of the body which encloses the blepharoplast is regarded by recent authorities as the *posterior extremity;* it varies greatly in shape and may be pointed or obtuse. The opposite end, the *anterior extremity*, tapers to a point, to which the flagellum is attached. Adjoining or surrounding the blepharoplast is a small non-staining area, the *vacuole*. The free border of the undulating membrane is somewhat thickened; this thickened border springs from the blepharoplast at one end, and its continuation at the other constitutes the flagellum. In certain specimens the cytoplasm is homogeneous; in other specimens comparatively faintly staining granules are visible. In comparing and measuring a large series of specimens, it becomes apparent that there is great diversity in the dimensions of the body of the parasite, the nucleus, and the flagellum (Fig. 46). Thus, some are short and stumpy, with short or no flagellum, measuring from 14 to 20 μ in length; others are long and slender—23 to 33 μ; others again are of intermediate dimensions—20 to 24 μ in length by 1·40 to 2 μ in breadth.

In certain instances evidences of multiplication by longitudinal division are seen. The process commences most frequently in the blepharoplast, which elongates, and then divides. The nucleus divides almost simultaneously, sometimes before the blepharoplast. The division of the blepharoplast is followed by the duplication of the thickened margin of the undulating membrane, beginning at its blepharoplast attachment; this, in its turn, is followed by longitudinal division of the whole body. According to Miss Muriel Robertson—an accomplished protozoologist working in Uganda—only a portion of the flagellum is split off with the daughter individual. The fission of the body is effected dorso-ventrally

but the resulting forms do not separate along the ventral border until the new flagellum has appeared, the final separation proceeding antero-posteriorly; parasites still adhering by their posterior extremities are occasionally encountered. The division forms are usually of about equal size, and slightly smaller than the parent form.

Crithidia-like forms have been found in the cerebro-spinal fluid and, according to Breinl and Fantham, latent encysted forms in the lungs, spleen, and bone marrow. Granule-shedding, similar to that described by Balfour in pathogenic spirochætes, has been observed by Fry and Ranken in the liver, spleen, bone marrow, and lymphatic glands. Wolbach has shown that in experimental animals trypanosomes are found in all organs, including the brain.

Although we are accustomed to observe the parasites in the blood, there is reason to believe that this is not their only principal habitat. As suggested by Mott, and proved by Greig and others, they are generally more easily found in the lymphatic glands, which are often markedly enlarged. They occur also in the cerebro-spinal fluid, and probably in the fluid of the serous cavities; facts pointing to the lymphatic system as an important habitat of the trypanosoma. As regards the blood, there is no uniformity in the number of parasites present: sometimes they are fairly abundant, one or two in each field of the microscope; at other times and in the same patient it may be difficult or impossible, even after prolonged search, to find a single specimen. In some cases they tend to recur cyclically at intervals of a week or more. On the whole, although this is by no means invariable, the parasites are most abundant in the blood during the febrile attacks to which these patients are so subject.

Formerly many attempts were made to cultivate *T. gambiense* on artificial media, but without marked success, notwithstanding that the parasite is readily communicated to monkeys, dogs, rats, guinea-pigs, and many other animals, though amphibia and reptiles are immune. Success was not attained till a suitable medium, termed the N.N.N. medium,* was discovered.

* The composition of this is as follows: Agar 14 grm., salt 6 grm., distilled water 900 c.c.; macerate carefully with fresh

On this medium Novy and McNeal have shown that *T. lewisi* and other trypanosomes multiply rapidly in the water of condensation, and that in many species subcultures can be carried on through an indefinite number of generations. Thus, *T. gambiense* has been cultivated for four generations; *T. rhodesiense* is much more difficult to cultivate. Unfortunately, *T. gambiense* is somewhat refractory and does not multiply readily in this culture medium. In such cultures, however, the trypanosome form may be lost, the flagellum springing directly from the anterior extremity and no undulating membrane developing. Cultivation is now utilized as a diagnostic method of demonstrating trypanosomes, if very scarce in the peripheral blood.

Interesting observations have been made by Laveran and others on a very striking phenomenon exhibited by trypanosomes, in certain circumstances, both in the blood and in artificial cultures. Upon the advent of unfavourable biological conditions in these media, such as the influx of sera of non-susceptible animals, increasing scarcity of nutriment (as in the alimentary tube of an appropriate invertebrate host), lowering of temperature, or the addition of chemical solutions to artificial cultures, the trypanosomes tend to congregate in bunches in which the posterior extremities of the parasites are apposed, the flagellated extremities remaining free (Fig. 44). One such group is termed a "primary" agglomeration, and may be composed of upwards of a hundred individuals. In many cases these primary clusters themselves become grouped together to form still larger tangled masses known as "secondary" agglomerations. Agglomeration does not of itself seem to have any ill effect on the constituent parasites, which may again disperse, apparently quite unaltered. Sometimes all the individuals forming a cluster become disagglomerated; at other times

water for twenty-four hours. After sterilization the agar is pipetted off into test-tubes and one-third volume of fresh rabbit's blood added. After sloping, the tube must be incubated to test sterility.

the break-up is only partial, a certain number of the more feeble and less mobile parasites remaining together and slowly dying. The significance of this phenomenon has yet to be ascertained. Some authors believe that it indicates a recuperative molecular interchange between the associates.

In cultures, in many instances, trypanosomes acquire a spherical form and undergo multiple divi-

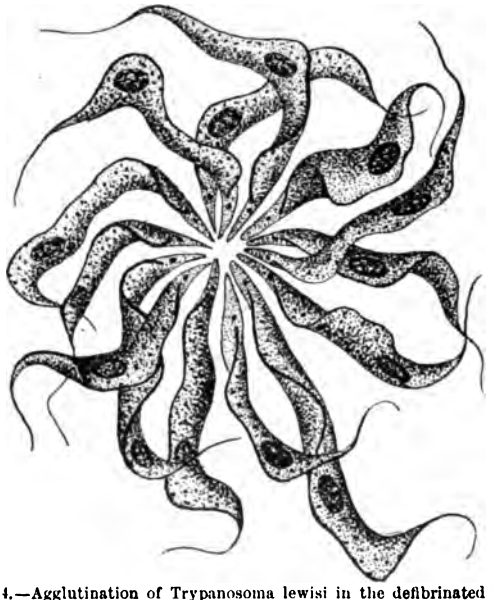


Fig. 44.—Agglutination of Trypanosoma lewisi in the defibrinated blood of an immunized rat. (*After Laveran.*)

sion. They lose their flagella in the process, certain of the division forms subsequently acquiring such an organ, which now invariably springs, as already mentioned, directly from the blepharoplast. These culture forms possibly represent a stage in the life of the parasite which, in normal conditions, is passed in the vertebrate host, or, more probably, in the insect host.

How long a trypanosome infection may persist in the human body has not been definitely determined,

but there is direct evidence that it may continue for several—three or four—years. From what we know of the incubation period of sleeping sickness it is not improbable that this period is sometimes greatly exceeded, and may extend to seven years or longer.

Extrusion of granules and their further development.—Fry and Ranken have recently described under this title a remarkable phenomenon which may have an important bearing on the life history

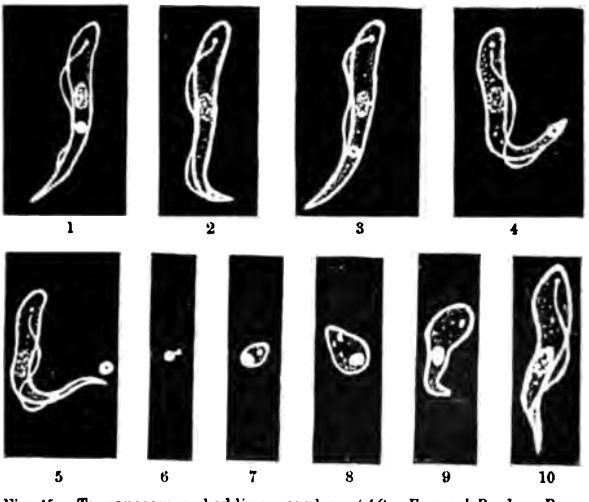


Fig. 45.—Trypanosomes shedding granules. (*After Fry and Ranken, Proc. Roy. Soc.*)

of the trypanosome (Fig. 45). Balfour describes a similar process in spirochætosis. It is specially observable in those more chronic forms of trypanosomiasis of man and animals, in which the trypanosomes disappear from the blood for considerable periods at a time, and may explain the occasional infectivity of blood in which the parasite cannot be detected with the microscope.

The observers referred to state that trypanosomes may or may not contain two kinds of granules, one kind being of the nature of food material, the

other, which is a sharply defined refractile body, being concerned in the process they describe. Their description refers to *T. gambiense*, but they have witnessed a similar process in other species of trypanosomes.

Referring to *T. gambiense*, they write :—

"In this species the granules are multiple and move rapidly backwards and forwards in the long axis of the trypanosome. They exhibit also a dancing movement and appear to throw themselves against the periplast and rebound from it. Sometimes the granules approach the surface, and in doing so may actually cause a slight protrusion on the covering membrane. This seems to be preliminary to extrusion, as afterwards the granule may be shot out with a certain degree of force into the free fluid to some distance from the host. In this species extrusion is not as a rule effected from the extremity (as in *T. nanum*), but from some point near the middle of the trypanosome body.

"Extrusion of granules, if occurring generally, apparently heralds a disappearance of trypanosomes from the blood and is, in fact, the precursor of a trypanolytic crisis. Under favourable circumstances, e.g. after treatment, extrusion is followed by rapid disintegration of the trypanosomes."

As regards the granules, they state that there is "a definite sequence of events during an exacerbation of the disease: (1) Trypanosomes without granules; (2) trypanosomes showing granules which gradually become larger and very evident; (3) many free granules; (4) many trypanosomes but no granules; (5) trypanolytic crisis, or death of the animal."

After extrusion the granules, which are now motile, if they escape the phagocytes, undergo the developmental change illustrated in Fig. 46.

Rôle of the tse-tse fly.—An important practical point is the question of the transmission of the parasite. As already mentioned, the well- and long-known rôle of the tse-tse fly* in the transmission of the trypanosome of nagana suggests that the corresponding parasite of man is transmitted by a corresponding insect, a suggestion borne out by considerations of distribution, and by experiment.

Minchin, Gray, and Tulloch have shown that when *Glossina palpalis* was half fed on a rat infected with the cattle trypanosome of Uganda (probably *T. brucei*), and immediately transferred to complete its meal on a healthy rat, in four out of five

* For a brief description of the tse-tse flies, see p. 194.

experiments the healthy rat contracted the infection; but if the transference was delayed, for an hour even, the experiment failed. As similar experiments with other blood-sucking flies (*Stomoxys*, for example) which, apparently, have no biological connection with *T. brucei*, succeeded to some extent, and as such a method of feeding can only occur exceptionally in nature, it is reasonable to infer that the closely allied *T. gambiense* is not usually

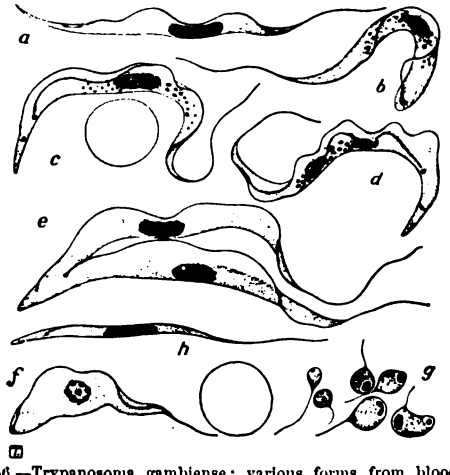


Fig. 46.—Trypanosoma gambiense: various forms from blood and cerebro-spinal fluid.

a, Elongated posterior extremity; *b*, blunt ditto: *c*, *d*, and *e*, dividing forms; *f* and *h*, probably sexual forms; *g*, small round forms from cerebro-spinal fluid.

communicated in this purely mechanical way. We know that the malaria parasite can be communicated by the direct inoculation of malarial blood, but it is universally admitted that direct inoculation is not the natural method of transmission. The idea that the glossina inoculated trypanosomes in this direct way originated, undoubtedly, with the interpretation that has been placed on Bruce's experiments with nagana, an interpretation which may be incorrect. It is true that both Bruce and Minchin communicated trypanosoma infection

to monkeys and other animals by means of tse-tse flies caught in the jungle. It is manifest, however, that before these tse-tse flies could have fed on the experimental animals an interval of many hours must have elapsed since their previous blood-feed. Therefore, in view of Minchin's failure to communicate the disease by insects that had been kept for only a short time after being fed on trypanosoma-infected animals, it is reasonable to conclude that there could have been no direct inoculation by these jungle-caught flies.

A more probable interpretation of the experiments, and one based upon what we know of the transmission of other hæmoprotozoa, is to the effect that glossina serves as an alternative host in a truly biological sense, and not as a simple mechanical transmitter; that the trypanosome, after entering the intestinal canal of the insect (Fig. 47), undergoes developmental changes requiring a considerable space of time for their completion, developmental changes which enable it subsequently, when the opportunity occurs, to effect a lodgment in the human or other vertebrate host. That this view of the rôle of the tse-tse fly is correct has been established by Kleine, who, after feeding *G. palpalis* on animals infected with *T. brucei*, set the same flies to bite fresh animals at various intervals. Up to twenty (possibly sixteen) days the flies failed to convey the infection, but from that period onwards to the forty-seventh day, when the experiment concluded, they communicated the trypanosome to eight animals. Bruce and others have confirmed Kleine's results and have ascertained that they apply to *T. gambiense* and other trypanosomes. It is estimated that 0·03–0·34 per cent. of wild *G. palpalis* in Uganda are infective; but in captivity, if fed on trypanosome-infected blood, 5–6 per cent. of flies become infective, and, according to Miss M. Robertson, a still greater proportion (21 per cent.) if the flies are starved after feeding. More recently Bruce and his co-workers have found that in Nyasaland 1·35 per cent. of all wild tse-tse flies are infected with one or other of

the disease-producing trypanosomes. It is to be noted that the trypanosome, at intervals not as yet

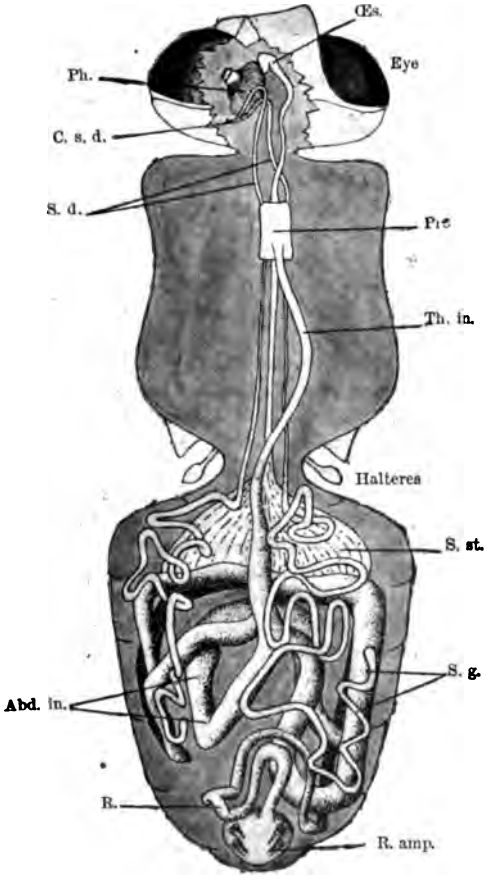


Fig. 47.—General view of digestive tract of *Glossina palpalis*. (*After Minchin, Report on Sleeping Sickness to the Royal Society.*)

Ph., pharynx; Œs., œsophagus; C. s. d., common salivary duct; S. d., salivary ducts; Pro., proventriculus; Th. in., thoracic intestine; S. st., sucking stomach; S. g., salivary glands; Abd. in., abdominal intestine; R., rectum; R. amp., rectal ampulla.

ascertained, is incapable of infecting the fly. For this observation also we are indebted to Miss M. Robertson.

The trypanosome-infected contents of the stomach of a glossina if injected into a susceptible animal do not communicate the infection, although the parasites may be alive at the time of the injection. Possibly the multiplying forms in the stomach are of the same sexual nature as those of malaria in the mosquito — gamete forms — and therefore incapable of multiplication in a vertebrate host. Koch for *T. brucei*, and Minchin, Gray and Tulloch for *T. gambiense*, state positively that the parasites show marked sexual differentiation within the stomach of the insect host.

The discovery by some of the above-mentioned investigators that jungle-caught tse-tse flies harbour a variety of species of trypanosome "wild forms," while only a small proportion of them convey *T. gambiense* (sometimes as many as a thousand of these insects were required before a successful infection of monkeys was obtained), makes it evident that extreme precision and care must be observed in order to eliminate sources of fallacy. That the tse-tse fly conveys the trypanosome is certain, and Koch's observation that trypanosoma forms may sometimes be observed in the blood-free droplet of clear fluid which can be expressed from the proboscis, as well as the conditions observed in experimenting, indicate that the infection is conveyed by the bite of the fly. But, even assuming that glossina has been proved to be the proper transmitter of *T. gambiense*, much remains to be done: the history of the trypanosome, from the time of its removal from one vertebrate by the glossina to its introduction into another vertebrate, has not been completed.

Minchin, having discovered encysted developmental forms of trypanosomes in the lower gut of the tse-tse fly, conjectured that the infection might be transmitted by the droppings of the fly when swallowed by man or other vertebrates. Further observation has not supported this conjecture.

Dealing with the entire life-history of *T. gambiense*, Miss Robertson summarizes her conclusions as follows:—

"1. *T. gambiense* undergoes an endogenous cycle of development in the vertebrate in the circulating blood. This cycle is of irregular duration and is repeated many times in the course of the disease.

"2. The short forms may be regarded as the adult blood-types; the intermediate types are growth-forms, proceeding to the long individuals, which are those about to divide. The products of division give rise, directly or indirectly, to the adult forms. The adult forms appear to be alone responsible for carrying on the cycle in the transmitting host.

"3. The multiplication occurs in the circulating blood.

"4. Multiplication of the parasites was never found within the cells of the liver, spleen, or lungs in monkeys.

"5. Rounded non-flagellate types were found on one occasion in the lung, liver, and spleen of a virulently infected monkey. They appear for the most part to be destined to destruction, but it is not excluded that they may survive in small numbers as latent forms.

"6. In the fly the trypanosomes are first established in the posterior part of the midgut. Multiplication occurs and trypanosomes of very varying sizes are produced.

"7. From the tenth or twelfth day onwards slender long trypanosomes are to be found in increasing numbers. These finally move forwards to the proventriculus and are the dominant, though not the only, type seen there. The proventriculus becomes infected as a rule between the twelfth and twentieth days.

"8. The salivary glands become infected by the slender proventricular types. They reach the salivary glands by way of the hypopharynx; arrived in the gland, they become attached to the wall and assume the crithidial condition. Multiplication occurs, and finally small trypanosomes are produced, closely resembling the blood type. The passage through the crithidial stage is characteristic of the salivary development, and the trypanosome forms just men-

tioned are derived from the crithidial types. The development in the salivary gland takes from two to five days before the forms are infective.

"9. The fly is never infective until the glands are invaded. Trypanosomes from the proventriculus when injected into a monkey never produce infection. Trypanosomes may be found in the salivary glands as early as the sixteenth day of the cycle. An early infection of the salivary glands is always preceded by a very virulent and rapid gut infection.

"10. The trypanosomes are never attached to the wall of the alimentary canal, and there is no intracellular multiplication in the gut cycle. A crithidial stage does not occur in the gut cycle. The trypanosomes are never found in the body cavity nor are they ever established in the rectum.

"11. Conjugation has not been observed, nevertheless the fly cycle as a whole has the biological significance of conjugation."

Considering the bionomics of glossina, it seems not improbable that some of the trypanosomes, after undergoing certain unknown changes, may enter the larva, and be thus transmitted by heredity to the vertebrate host. This has been suggested by Sambon. So far, however, such hereditary transmission has not been established. Yet it may be pointed out that it would conform in a remarkable manner to the habits of the babesiæ in relation to their invertebrate transmitters.

To settle these and other questions of great practical importance in connection with the rôle of the tse-tse fly in trypanosomiasis, experiments with laboratory-reared insects are indispensable; and, further, observations should be extended to all the species of the genus. We have no assurance that *Glossina palpalis* and *G. morsitans* are the only efficient transmitters. Direct infection through breaches of surface or through mucous membranes (e.g. during coitus, as has been suggested by Koch) cannot be entirely excluded as a possibility.

Predisposing causes.—Neither age, sex, occupation, nor race *per se* has any influence on the

susceptibility to trypanosoma infection, except in so far as they conduce to opportunity. Thus occupations (boatmen, fishermen, water-carriers) which imply a frequenting of the waterside haunts of the glossina conduce to infection.

Incubation period.—The incubation period of the glossina-conveyed disease and that resulting from direct artificial inoculation seem to be about the same, from two to three weeks—in the case of dogs, horses, and monkeys. As regards man, observations are too few to warrant anything like a definite statement on the point, but in one or two instances circumstances seem to point to a similar incubation period.

Symptoms.—Without being too definite on the point, and basing the statement on the experience of a limited number of cases, I would suggest that the bite of an infected glossina is followed, in a proportion of cases, by a degree of local irritation of greater or less severity. This subsides in the course of a few days, to be followed, sooner or later, by fever which may last a week or longer, and which may be accompanied by the appearance, in Europeans at all events, of a peculiar type of erythema and a certain amount of serous infiltration of the connective tissue. A form of hyperæsthesia, known as "Kerandel's symptom," is usual, though not invariable; if the patient strikes a limb against any hard object, a degree of discomfort amounting to actual pain is experienced, the sensation being slightly delayed. In time the fever subsides more or less completely, to recur at irregular intervals of days or weeks. The fever is sometimes mild, sometimes severe, and occasionally hyperpyrexial (106·6° F.), the evening temperature being always the higher. The fever may last for weeks; the apyretic period may be equally prolonged. On the other hand, the fever may be continuous, or the apyretic period may last for months. Irregularity of degree and duration is a feature of the fever and, also, of the other clinical manifestations of trypanosomiasis. In time the patients become debilitated, anæmic, feeble both intellectually and physically. Headache is very often complained of. The heart's action is generally

rapid and easily excited. The cervical glands and the glands of other parts of the body enlarge and may become tender. It may be that only one gland is visibly involved, or there may be a recognizable general polyadenitis, including the abdominal glands. The implicated glands may be very prominent, or they may not be easily felt. In the early stage of the infection they are soft, later they are indurated. Sometimes they are painless, sometimes distinctly painful and tender, rarely suppurating. This condition of irregular fever, of debility, of polyadenitis, of slight anæmia, may go on for months, or even, in some instances, for years.

There is reason to hope that in a proportion of cases the disease may terminate at this stage. I know and have seen three cases in which after many months of illness the symptoms entirely disappeared, and have been absent for several years, during which the parasite could no longer be found in the blood, whether tested by microscope or by animal injection (two cases). But, considering that the disease may present at various stages periods of quiescence which, in some instances, may be very prolonged, it would be rash to say whether in any instance of apparent recovery we are dealing with a radical cure, or merely with one of these long periods of latency. Experiments and observations by Laveran and others in other forms of trypanosoma infection, as well as cases of the disease in Europeans, justify the belief that occasionally the parasite does die out, either spontaneously or as a result of treatment.

Remarkable features of human as well as of animal trypanosomiasis are the skin affections and the local œdemas. In many of the lower animals affected with their special trypanosomes, in addition to fever and physical lethargy, papular and pustular eruptions are not uncommon, and in man, especially in negroes, an exceedingly itchy papular eruption is a common symptom. In the European, and possibly in the negro, but in the latter in consequence of his colour not so evident, extensive skin areas are affected with a fugitive, patchy, frequently annular erythema (Fig.

48), usually most evident on the chest and back, but also very often on the face and elsewhere. This erythema seems to occur most frequently and most distinctly in the earlier stages of the infection. Some of the

Fig. 48.—Rash of human trypanosomiasis. (*From photo by R. McKay.*)

patches may extend to six inches or even to a foot in diameter, their margins fading off insensibly into the surrounding normal skin. Sometimes the erythema takes the form of large rings, occasionally complete, more frequently interrupted and irregular. Erythema nodosum sometimes occurs. Pressure or

any irritation of the skin gives rise at once to transient congestion from vaso-motor paralysis of the skin capillaries.

In some of the lower animals a usual feature is œdema of certain parts of the body, especially the sheath of the penis, the under surface of the abdomen, and the neck. Similar though less extensive œdemas occur in man, in whom they are most apparent about the face and about the site of the erythema. In many instances there is a general fullness of the features, which, together with concomitant flushing of the face, is apt to convey a false impression of sound health.

Neuralgic pains, cramps, formication and paræsthesiæ of different kinds are not uncommon. In two of my European cases recurring orchitis, accompanied by an increase of parasites in the blood, was a feature. Painful local inflammatory swellings, which after a time subside without suppuration, I have seen in three cases; periostitis of tibiæ once. Irido-cyclitis and choroiditis are sometimes met with.

In most cases the spleen is enlarged, sometimes enormously enlarged, the swelling fluctuating with the fever. The liver, also, may be enlarged. As the patients affected with trypanosomiasis are usually the subjects of malarial disease, it is not always possible to say whether the splenic enlargement is entirely or partly attributable to the trypanosome.

Death from intercurrent disease, or from rapidly developing cerebral implication causing convulsion, the status epilepticus, coma, etc., may supervene at any stage of trypanosomiasis. Usually the case gradually drifts into the stage known as "sleeping sickness."*

Sleeping sickness.—The condition known as sleeping sickness may be regarded as the terminal stage of trypanosoma infection. Sometimes it exhibits acute features, sometimes it is exceedingly chronic. From the commencement of the infection to the development of this terminal stage, in a propor-

* It is customary to state that the development of the sleeping-sickness stage in trypanosomiasis concurs with and is dependent on the entrance of the parasite into the cerebro-spinal canal.

tion of instances an interval of many years, possibly seven, may elapse. In the majority of cases the march of events is much more rapid. The characteristic terminal symptoms depend on implication of the nervous system, either by the parasite itself or by its toxins.

According to Low and Castellani, the average duration of this stage of trypanosomiasis in the African is from four to eight months, not infrequently less; very chronic cases with a course of more than a year's duration are rare. Other observers refer to cases running on for three years, or even longer, and presenting occasionally temporary ameliorations.

Generally the first indications of the oncoming of sleeping sickness are merely an accentuation of the debility and languor usually associated with trypanosoma infection. There is a disinclination to exertion; a slow, shuffling gait; a morose, vacant expression; a relaxation of features; a hanging of the lower lip; a puffiness and drooping of the eyelids; a tendency to lapse into sleep or a condition simulating sleep; a slowness in answering questions; a shirking of the day's task. Dull headache is generally present. Later there may occur fibrillary twitching of muscles, especially of the tongue, and tremor of the hands, more rarely of the legs, indicating a definite implication of the motor centres.* By this time the patient has taken to bed, or he lies about in a corner of his hut, indifferent to everything going on around him, but still able to speak and take food if brought to him. He never spontaneously engages in conversation or even asks for food. As torpor deepens he forgets even to chew his food, falling asleep perhaps in the act of conveying it to his mouth, or with the half-masticated bolus still in his cheek. Nevertheless, such food as he can be got to take is digested and assimilated. Consequently, if he is properly nursed, at this stage there may be no

* In German East Africa, out of 55 patients in the last stages of the disease only 5 had sleep symptoms. Exophthalmos was noted 16 times.

general wasting. As time goes on he begins to lose flesh, tremor of hands and tongue becomes more marked, and convulsive or choreic movements may occur in the limbs or in limited muscular areas. Sometimes these convulsions are followed by local temporary paralysis. Sometimes there is rigidity of the cervical muscles and retraction of the head. Bedsores tend to form, the lips become swollen, the saliva dribbles from the mouth. Gradually the lethargy deepens, the body wastes, the bedsores extend, the sphincters relax, and finally the patient dies comatose or sinks from slowly advancing asthenia. Possibly he succumbs to convulsions, hyperpyrexia, pneumonia, dysentery, or other intercurrent condition.

The manifestations described are subject to considerable variations. Mania is not uncommon; delusions may present themselves, or psychical and physical symptoms not unlike those of general paralysis of the insane are developed.

During the whole course of the nervous stage of trypanosomiasis the other symptoms already described as characteristic of the infection may be in evidence. The knee-jerks, though lost towards the end, are active at first; the fundus oculi is normal; the sphincters, until towards the end, are controlled; the urine is normal, and the bowels, although generally tending to constipation, act with more or less regularity.

Mortality.—Although spontaneous recovery may take place in the early stages of trypanosomiasis, when the disease has arrived at the stage of sleeping sickness death, it is believed, is inevitable. Corre has told us how native villages in Senegambia have been depopulated. What has occurred on the Congo, in Angola, and recently in Uganda, bears out this estimate of the gravity of the disease when it appears in epidemic form. We know that many islands on the Victoria Nyanza have been completely depopulated; and if it be true for a large part of the country, as Bruce has shown to be the case at Entebbe and its neighbourhood, namely, that 30 per cent. of the population harbour trypanosomes, the outlook for Uganda and neighbouring countries is grave indeed.

The population of the implicated districts of Uganda, originally about 300,000, has been reduced in six years to 100,000 by sleeping sickness.

Morbid anatomy (Fig. 49).—No gross lesions of the nerve centres, or of any other organ, have been described as invariably present; but in every case indications, principally microscopical, of an extensive meningo-encephalitis can be demonstrated. In a

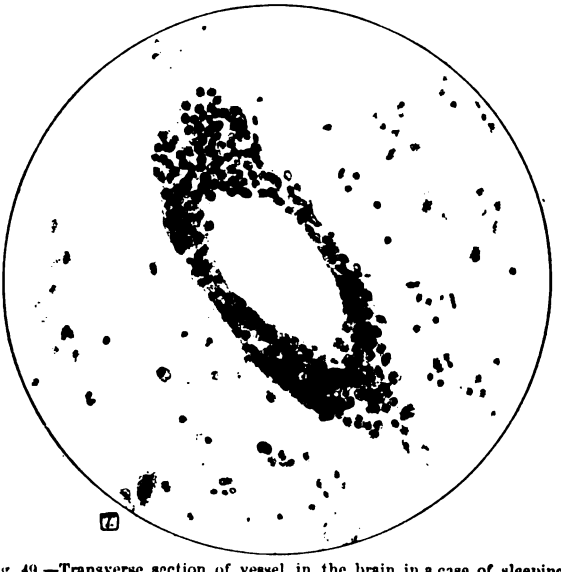


Fig. 49.—Transverse section of vessel in the brain in a case of sleeping sickness. (*From photo after Bettencourt.*)

proportion of instances congestion of the meninges, effusion of lymph, increase and turbidity of cerebro-spinal fluid, are found. In all cases, as first pointed out by Mott, there is an extensive small-cell infiltration of the perivascular lymphatic tissue throughout the brain, cord, and meninges, varying in amount in different cases and in different anatomical regions. This, the essential pathological feature of sleeping sickness, recalls the very similar condition in general paralysis of the insane.

The nervous elements exhibit secondary degeneration changes.

Similar changes are described by Mott in the nervous system in dourine, and chronic trypanosomiasis in the monkey. Mott has also pointed out that the lymphatic tissues throughout the body are similarly affected.

Bettencourt and other Portuguese observers, as well as Castellani, have described a diplococcus in the brain in sleeping sickness. This organism is in no sense causally related to the disease; it must be regarded merely as a terminal and non-essential epiphenomenon. Similarly, *Filaria perstans* (which at one time, in consequence of considerations of frequency of concurrence and geographical distribution, was regarded as being possibly the cause of the disease), the various intestinal worms, and *Schistosomum hæmatobium*, though often met with in sleeping sickness, are present only as accidental concurrences.

Diagnosis.—Chronic irregular fever, more especially if associated with enlarged cervical glands and, in the European, erythema multiforme, in a patient who has resided in tropical Africa at any time during the previous seven years, but more especially recently, suggests a tentative diagnosis of trypanosomiasis and detailed examination with this possibility in view. Diseases with which trypanosomiasis might be confounded are malaria, kala-azar, pellagra, syphilis, leprosy, and, in its later stages, beriberi.

Malaria, syphilis and leprosy are easily excluded. As regards beriberi, there should be no difficulty if it be borne in mind that it is a disease of the peripheral, whilst trypanosomiasis is a disease of the central nervous system; that beriberi is non-febrile, and that trypanosomiasis is febrile. Kala-azar and trypanosomiasis, especially in their earlier stages, may be more difficult to differentiate; but the presence of enlarged glands, local œdema, and erythema multiforme in trypanosomiasis, and their absence in kala-azar, suffice for distinction. Blood or gland-lymph examination, or, if this be negative, hepatic or splenic puncture, should establish the diagnosis.

In pellagra the erythema is of a characteristic type. It is not ringed or fugitive as that of trypanosomiasis, and it affects principally the exposed parts of the body; the disease is of a much more chronic character, and, instead of lethargy, the mental condition, if implicated, is more that of insanity—melancholia alternating with mania and terminating in dementia. Further, in pellagra, the symptoms are aggravated at particular seasons—spring and autumn.

General paralysis of the insane,* cerebral tumour, forms of meningitis, have features in common with trypanosomiasis and must be considered in diagnosis.

The microscopical diagnosis of trypanosomiasis is sometimes difficult. Anæmia as well as a large mononuclear leucocytosis occurs in trypanosomiasis. A wet blood preparation exhibits, even to the naked eye, a remarkable clumping of the red corpuscles. Held up to the light, such a preparation has a peculiar granular appearance, produced, as can be seen on microscopical examination, by agglomeration of the corpuscles into heaps and clusters, the usual rouleaux arrangement being absent. Such a disposition of corpuscles is significant of, though not peculiar to, trypanosoma infection. As a rule, the parasites in the peripheral circulation are few in number, many fields having to be hunted before a single example is discovered. Sometimes none can be found; rarely are they abundant. In the same case they are sometimes present, sometimes absent. Centrifuging the blood is not of much assistance. Dutton and Todd have emphasized the value of lymphatic-gland puncture and examination of the aspirated lymph, particularly in the earlier stages of the disease when the glands are soft and before they have become sclerosed; then the trypanosomes are fairly abundant in the lymph. An ordinary hypodermic syringe suffices to aspirate a sufficiency of lymph. Films of the lymph so obtained are prepared and stained in the ordinary way. Cerebro-spinal fluid, obtained by lumbar puncture and centrifuged, affords another

* The Wassermann reaction is of little avail, as unfortunately the sera of most cases of trypanosomiasis give a positive result.

though not always a practicable means of finding the parasite.

Failing discovery of the parasite by blood or lymph examination, recourse must be had to animal inoculation, 10 to 20 c.c. drawn from a vein being used for that purpose. Of the ordinary laboratory animals the most susceptible, and therefore reliable, are the guineapig, the rat, the dog, and certain monkeys—*Macacus* and *Cercopithecus*. Such inoculations are of value as a test of recovery, as well as for diagnosis.

The trypanosome is easily stained by most dyes; convenient stains are those in use for malaria work. A sixth objective suffices to find the parasite.

Treatment.—Although something may be done to relieve symptoms and delay the fatal issue in the sleeping-sickness stage of trypanosomiasis, it is only in the earlier stages of the infection and by the persistent and energetic use of arsenic or antimony, or both, that a cure can be effected, and that in a proportion of cases only. Other drugs have been shown to have some influence on the trypanosome infections of the lower animals, but their therapeutic va'ue in those of man is practically negligible.

The effects of the administration of *arsenic compounds* on a heavily infected animal are very marked, after a preliminary and marked increase in their numbers in the peripheral circulation. According to Thomas, in from three to seven hours an adequate dose of atoxyl causes the trypanosomes to become swollen, deformed, and almost motionless, their cytoplasm taking on a peculiar ground-glass appearance, becoming vacuolated, and presenting large dark granules. After seven or eight hours, coincidently with a marked increase of leucocytes—especially phagocytes—the parasites become rapidly fewer in number, and by the sixteenth or eighteenth hour completely disappear.

Arsenic, in the form of Fowler's solution or of orpiment, is sometimes given by the mouth; but this way of administering the drug, especially in Europeans, has been quite superseded by the intramuscular injec-

tion of a variety of relatively feebly toxic preparations, including atoxyl, soamin, arseno-phenylglycin, arsacetin, salvarsan,* etc.

Atoxyl, a meta-arsenic-anilin compound, introduced by Thomas, is probably the best of these, and the one most usually employed. Unfortunately it has one serious drawback—in large doses it is apt to give rise to optic neuritis, and consequent atrophy and blindness. The drug, therefore, must at once be stopped on the slightest threatening—dimness of vision or congestion of the disc—of such a calamity. Gastro-intestinal irritation and peripheral neuritis are also indications that it has to be suspended, at least temporarily, and the subsequent dose reduced.

Atoxyl is best given intramuscularly in 10 per cent. solution in sterile normal saline. The solution should be freshly made and free from precipitate. The individual dose should not exceed 7 or 8 gr. The practice as regards dosage and the times and frequency of administration varies. Some advocate a 7-gr. dose once every fifth day until symptoms subside. After a few weeks, similar courses, lasting for a month and repeated at short intervals, are kept up for at least one year. My practice has been to give an injection of 3 gr. every third day, and to keep this up uninterruptedly for two years, unless symptoms of arsenical poisoning show themselves, when the course is temporarily intermitted. I have seen excellent results from this method of giving atoxyl, both alone and in combination with tartar emetic by mouth or intravenously.

Antimony in the form of sodium tartrate hypodermically has been shown by Plimmer and Thompson to cause, without the production of serious local irritation, almost immediate and often permanent disappearance of *T. lewisi* in infected rats. In two cases of trypanosomiasis in man in which I used this drug intramuscularly the consequent local pain and irritation (culminating in tissue necrosis) were so

* Broden and Rodhain report good results on the Congo by intravenous injection of salvarsan; they insist that it is only of benefit in those cases where invasion of the spinal cord is negatived by microscopical examination of the spinal fluid.

excessive that in this form the treatment had to be abandoned. One of the patients, however, continued the drug by mouth to the extent of 1½ to 2 gr. daily, very highly diluted, a little being given in all his food and drink, and along with atoxyl injections, for over two years. He appears to be quite well.

The value of antimony (tartar emetic) in the treatment of trypanosomiasis is so marked that, if possible, it should be employed in every case. It is far too irritating for intramuscular injection. It can be given, freely diluted in normal saline, per rectum; but the efficacy of this method of administration has not been proved. Though troublesome and not free from risk, the intravenous method is the best and the one now generally adopted. The dose is ½ gr., gradually increased to 1½ gr., in 6 oz. or thereabouts of sterile normal saline.

The solution must be slowly introduced, and great care taken that none of it escapes into the connective tissue surrounding the vein. Pain and swelling, and perhaps abscess, are apt to follow such an accident. With this in view it is well, before pouring the emetic solution into the receiver of the transfusing apparatus, to place in the latter an ounce or two of plain saline, and, when the emetic solution has nearly all run through, a similar quantity of saline.

Not infrequently during the progress of the transfusion the patient is seized with a fit of coughing, or with feelings of constriction of the chest and faintness. If these are severe they may be regarded as indications for stopping the flow of fluid. Usually, though not always, the transfusion is followed by smart fever which soon subsides. A similar occurrence may follow intramuscular injection of atoxyl, and has been attributed to toxins liberated from the trypanosomes killed by the drug.

As with atoxyl, there are differences in the methods of employing antimony injections. Some give them daily in courses of fifteen days at intervals of fifteen days; others, once a week; others, again, according to indications supplied by tem-

perature and the microscopical examination of the blood. As with atoxyl, after the short fever which may ensue, the administration of antimony is usually followed by marked relief of symptoms.

Unless contra-indicated, atoxyl and antimony treatment should be combined or alternated. One or both should be instituted immediately the diagnosis of trypanosomiasis is established.

As pointed out by Ehrlich, certain strains of trypanosomes are "arsenic-fast," that is, they resist the action of the drug—a property which becomes hereditary and is continued in sub-inoculations into the lower animals. This undoubtedly accounts for the failure of arsenical treatment in a large proportion of cases. Presumably there are strains having a similar resisting power to antimony. As the atoxyl-fast trypanosomes may respond to antimony, and vice versa, both drugs should be employed in every case. In the face of so grave a disease great risks are justified.

According to Laveran, Roudsky, Kudicke, and Werbitzski, at times the acquired drug resistance is accompanied by a change in the morphology of the trypanosome. In *T. brucei* this resistance to parafuchsin and oxazine is accompanied by a disappearance of the blepharoplast, and this feature persists on sub-inoculation in untreated animals (even as far as the 140th sub-inoculation), but is lost immediately the trypanosome is passed through the appropriate definitive host.

In the treatment of trypanosomiasis, concurrently with the use of drugs, every effort should be made to keep the patient in good general health. Rest, warmth, and residence in a cool and healthy climate, the systematic use of quinine for any concurrent malarial infection, and the avoidance of fatigue and everything that might depress, should be insisted on.

The idea of cure must not be entertained until the patient has been free from all symptoms for many months, nor until the repeated injection of several cubic centimetres of his blood has failed to induce trypanosomiasis in susceptible animals.

Immunization.—Attempts have been made to procure a curative and immunizing serum, but, although a certain amount of success has attended these efforts in respect to the lower animals, as regards man they have failed.

Prophylaxis.—The indications for prophylaxis are based principally on the habits of *Glossina palpalis* and the existing conditions as regards the presence of the infection in a locality.

In endemic regions the fly areas should be located and avoided. If such regions have to be traversed the journey should be made during dark nights, when tse-tse flies do not feed, or with such precautions as are used by the natives for the protection of their cattle in nagana-infected spots. Those who are compelled to live in tse-tse regions should have their houses and persons carefully guarded against the fly. Manifestly it is desirable —whether it is feasible is another question — to avoid localities in which the natives are affected, and to prevent the infection of the local tse-tse flies by surrounding people having trypanosomes in their blood with mosquito netting; or by other measures, such as removing them from the usually very limited fly area to some neighbouring fly-free spot. Movements of infected individuals towards hitherto uninfected countries must necessarily be attended with great risk of the introduction of the disease. Whether such movements can be prevented in savage lands depends greatly on local circumstances. Wherever possible they should be prevented. Dutton and Todd suggest that an easily ascertained condition, more or less general in trypanosomiasis, namely, enlargement of the cervical glands, should be employed in eliminating dangerous individuals. Many years ago slave-dealers used such a method to shield themselves from loss. As a rough test it has some value. But we know that in some cases of trypanosomiasis the glands are not appreciably enlarged at all times, so that such cases could easily slip through a quarantine station. Moreover, as the cervical glands are often enlarged in other conditions, an injustice

might be done in enforcing such a measure in every instance.

Hodges and his colleagues in Uganda inform us that the fly ground proper is always a very narrow strip indeed, not more than ten to fifteen yards, and always along the water's edge; and that the insects very rarely extend their feeding beat beyond sixty yards of this, whether on the land side or on the water side. It is true they may follow with great persistency a man who has just passed through this narrow belt, for several hundred yards, rarely as far as half a mile; but it is obvious that if the ten or fifteen yards at the water's edge be made unsuitable for the fly, as can readily be done by clearing it of jungle, there will soon be no flies to follow, and the place will become safe. Therefore, where feasible, fly spots, where there are landing-places, ferries, wells or roads, should either be avoided altogether or be cleared of jungle for some yards—to be safe, thirty—from the water's edge. This is a practical measure of proved value in Uganda.*

Fly-traps, cloths smeared with Cleve's tse-tse fly lime and placed on a native's or donkey's back, have been tried on an extensive scale, but so far little or no diminution of the number of flies has been noted in any given area.

Koch, from observations in Uganda, suggested that trypanosomiasis may be communicated by the male during coitus. The phenomena of dourine and recent animal experiments support the idea, although the experiments referred to indicate that the risk is not great.

A complete scientific prophylaxis can be indicated with certainty only when we have full knowledge (1) of the habits of the tse-tse flies and of the reasons for their restriction to very limited and apparently capriciously distributed areas; (2) as to what verte-

* Duke has tried the injection of prophylactic doses of arseno-phenylglycin in the monkey and subsequent development of the trypanosome in the tse-tse fly. He finds that a monkey thus injected cannot be subsequently infected by a positive fly, and that the development of the trypanosome in the tse-tse fly is inhibited by imbibing drug-containing blood.

brates under natural conditions are normally hosts of *T. gambiense.* Experiment has shown that the glossina will bite any vertebrate, and that it can infect a large variety of mammals with the trypanosome. If this be the case in the laboratory it is reasonable to suppose that it is the case in nature also. Therefore, in the endemic regions of trypanosomiasis, the vertebrate fauna has to be reckoned with as a source and reservoir of infection.

In Uganda and elsewhere, principally with a view of preserving the hitherto uninfected from trypanosome infection, Government removed the entire population of the Sesse Islands and neighbouring shore of Lake Victoria Nyanza to fly-free areas in the interior. It was hoped that, the human source of trypanosome supply being thus denied them, the tse-tse flies would cease to be infective. Unfortunately, this hope has been disappointed. Three years after depopulation of the districts involved, Bruce ascertained that the local flies could still convey the disease to laboratory animals. Manifestly, *T. gambiense* can flourish under natural conditions in vertebrates other than man. The large game is now regarded as a probable reservoir for *T. gambiense*, as it is known to be for the *T. brucei* of nagana.

The introduction of *T. gambiense* into other countries is a grave possibility. It is true that it must have been frequently introduced into America in the days of slave importation and that it did not spread there; but as regards India and other Asiatic countries, which hitherto have had little or no communication with the West Coast of Africa, the experience has not been made on a large scale, and we have no assurance that if introduced the parasite would not find some appropriate transmitter. According to some authorities, nagana and surra are the same disease; if so, the causal trypanosome can be transmitted by blood-sucking flies other than the tse-tse. What holds good for *T. evansi* and *T. brucei* might equally apply to *T. gambiense.* Furthermore, the possibility of the introduction of the fly host of

the trypanosome of sleeping sickness, *G. palpalis*, into other tropical countries must not be lost sight of.

Trypanosoma Rhodesiense

The discovery by Stephens and Fantham that the trypanosome found in sleeping-sickness cases originating in Nyasaland and Rhodesia presented certain peculiarities when passed through the rat, that it was associated with a highly virulent and resistant form of the disease,* that animals immunized against *T. gambiense* succumbed to the Rhodesian trypanosome, and especially, as proved by Kinghorn and Yorke, that it was transmitted by *Glossina morsitans*, justifies the conclusion that, if not a distinct species, *Trypanosoma rhodesiense*, as it has been named, is a very definite variety, and that in practice it must be regarded as such.

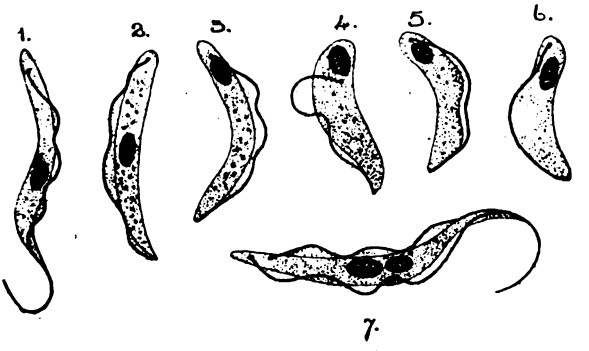


Fig. 50.—Trypanosoma rhodesiense. (*After Laveran.*)
1 and 2, Normal forms in blood of man; 3-6, various stages of posterior displacement of the nucleus; 7, a dividing form.

In human blood (Fig. 50), *T. rhodesiense* is morphologically indistinguishable from *T. gambiense;* but if it is passed through the rat a small but variable proportion of the parasites, especially the stumpy forms, will be seen to have their nuclei located posteriorly to the blepharoplast, that is to say, at the non-

* No enlargement of the lymphatic glands is said to occur in the victims of this infection.

flagellar end of the organism. It also, as occasionally in man, exhibits a marked periodicity, disappearing from the blood-stream for weeks at a time.

Glossina palpalis has not been met with in Rhodesia and Nyasaland; its rôle as regards the trypanosome is filled by *Glossina morsitans*.

According to Kinghorn and Yorke, these peculiarities in the range, distribution, and fly intermediary of *T. rhodesiense* receive their explanation in the circumstance that the developmental cycle is dependent on atmospheric temperature. High temperatures (75°–85° F.) favour development in the fly, low temperatures (60°–70° F.) are against it.

The same observers have ascertained that the large game of the country is a reservoir of the parasite. In view of this, Yorke has advocated as an experimental sanitary measure the extermination of this interesting fauna. Seeing that this terrible disease is spreading, and that it has already crossed the Zambesi, that the range of *G. morsitans* extends as far south as Zululand, that this species of glossina is not so circumscribed topically as *G. palpalis*, and that it is believed to be in great measure dependent on these animals, the destruction or driving back of the large game in morsitans countries seems to be the only measure likely to avert what might otherwise prove to be an immense calamity.

Later experiments by Bruce and his co-workers have shown that *T. brucei*, when injected into rats, exhibits the same proportion of posterior-nucleated forms as *T. rhodesiense*. From this and other facts these observers suggest that *T. rhodesiense* is none other than *T. brucei*, that 37 per cent. of the wild game in the fly-country harbour pathogenic trypanosomes, and that the waterbuck, hartebeest, reedbuck, and duikerbuck are a source of danger to man.

Taute, who has recently carried out much research work on this important subject in Portuguese Nyasaland, does not agree in all respects with the views of Kinghorn, Yorke and Bruce. He points out that the trypanosomes in naturally infected game or domestic animals can be regarded as a potential cause

of sleeping sickness only if they are actually shown to be pathogenic to man; and he maintains that the wild game and domestic animals do not play any part in the spread of sleeping sickness, at all events in the sense of Kinghorn and Yorke. Merely to infect laboratory animals with a trypanosome morphologically identified with *T. rhodesiense* does not prove that this trypanosome is *T. rhodesiense*, or that the district from which the trypanosome came is a sleeping-sickness area. He says that in East Nyasaland *T. brucei* can be distinguished from the trypanosome of sleeping sickness only and solely by the fact of its non-pathogenicity to man. Taute supports these views by some very significant experiments. *G. morsitans* fed on animals infected with *T. brucei* were subsequently fed to two men; the result was negative, though a number of control animals fed simultaneously died. Taute infected himself with 2 c.c. of blood from a trypanosome-infected dog, the trypanosomes being of the Rhodesian type; there was no bad effect. Fourteen days later he injected 90 c.c. of his own blood into susceptible animals; these animals did not become infected—showing that the human organism has the power to kill this particular trypanosome. Whether Taute is right or wrong in his views, it must be conceded that he has the courage of his opinions.

Atoxyl and antimony, generally so potent against *T. gambiense* infection, seem to be powerless in the sleeping sickness of Rhodesia.

Trypanosoma Cruzi (Schizotrypanum Cruzi)

Chagas has shown that a form of trypanosomiasis, especially common in children, is endemic in parts of the state of Minas Geraes in Brazil, and that it is transmitted to man and the domestic animals by a species of bug, *Lamus megistus* (at first erroneously supposed to belong to the genus Conorhinus). Allied species and certain other biting insects appear to have the power of transmitting the infection, at all events under experimental conditions.

Symptoms.—The disease assumes a variety of aspects according to the organs more particularly affected by the parasite, individual susceptibility, and the occurrence of reinfection. It is frequently fatal, and in those who recover is apt to entail conditions, physical and mental, resembling cretinism.

Chagas recognizes acute and chronic types. In the former, shortly (ten or more days) after the bite of the transmitting insect, which is painful, high fever supervenes together with enlargement of the thyroid gland, lymphatic glands (especially the cervical), spleen, and liver, myxœdematous swelling of the face, and transient œdemas in different parts of the body. There may be indications of meningo-encephalitis. These symptoms come and go during a variable period, and terminate either in death, or in recovery, or in the chronic form lasting for years.

In the chronic form there is well-marked enlargement of the thyroid, with accompanying myxœdematous symptoms, as loss of hair, mental debility, etc. The lymphatic glands are always enlarged. In some instances there is marked bronzing of the skin, as in Addison's disease, depending on implication of the suprarenal capsules. In others, where the brunt of the infection has fallen on the heart, there is great irregularity in the action of this organ. In yet others aphasia, ataxia, spasm, athetosis, tremor, or other nervous symptoms indicate that brain, or spinal cord, or both have become implicated. Generally there is a combination of several of these conditions. Throughout, an irregular fever comes and goes, and there is always pronounced anæmia.

The chronic form is that most commonly encountered in youths or adults—probably carried on from infancy or childhood, or kept up by re-infection.

The parasite.—During the febrile attacks the parasite (Fig. 51) in variable numbers is to be found in the blood, free or, rarely, partially included in red blood-corpuscles (Chagas). It averages about 20 μ in length and has the usual trypanosome characters.

The undulating membrane is narrow and the nucleus and blepharoplast are large. It is easily cultivated.

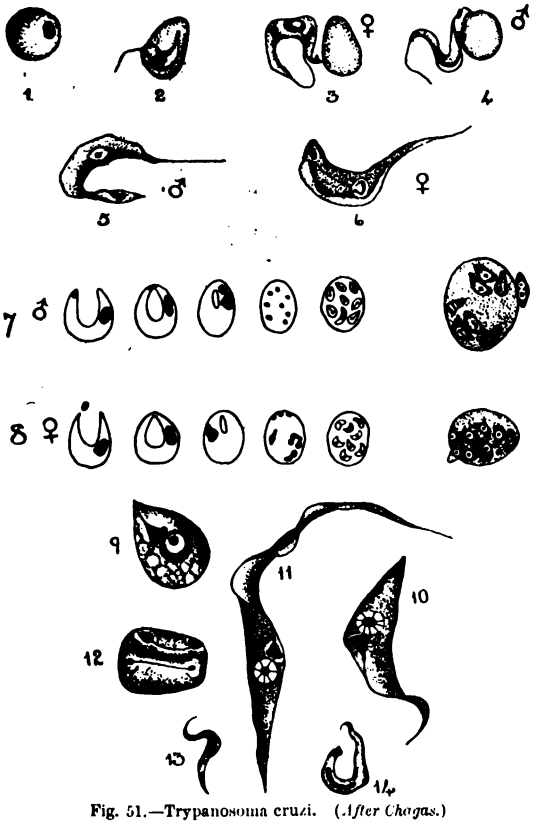


Fig. 51.—Trypanosoma cruzi. (*After Chagas.*)

Figs. 1-6.—*Forms in human blood:*
1, 2, Supposed endocorpuscular forms; 3, 4, trypanosomes adhering to red cells; 5, 6, so-called male and female forms.
7 and 8.—*Schizogony in the endothelial cells of pulmonary vessels in man:*
(Diagrammatic representation of the pulmonary cycle, cyst formation and liberation of young trypanosomes. It is doubtful whether ♂ and ♀ cycles as described by Chagas really exist.)
9-14.—*Forms found in Lamus magistus:*
9 and 10, Forms from midgut showing development of flagellum; 10 and 11, forms from the hindgut; 12, simultaneous division of nucleus and centrosome; 13 and 14, forms from salivary gland under a lower magnification.

After ingestion by the insect intermediary the trypanosomes multiply in the gut. Some pass out

with the fæces, which thus become infective if inoculated into a wound, or if applied to a mucous surface as the conjunctival sac (Brumpt). This, however, is not the normal way in which the infection is conveyed to man. In the midgut crithidia forms develop and, at a later stage, minute trypanosoma forms. It is the latter that, passing into the salivary glands, become the agents by which the infection is established. Eight days elapse after feeding on infected blood before the bug itself becomes infective.

Arrived in the human body the parasite multiplies, not in the blood (dividing forms are never found there), but in the cells of various organs, including the striped muscular fibres, especially of the heart, back, and lower extremities; in the bone marrow, the thyroid gland, suprarenal capsules, nerve fibres and cells, testes, connective tissue, and other organs. Arrived in these it assumes a leishmania form (Fig. 56), divides and subdivides, distending the including cell till this becomes a mere cyst in which the parasites revert to the trypanosoma form. The cyst then bursts and the trypanosomes escape into the tissues, ultimately finding their way into the blood concurrently with an attack of fever. This is the form of schizogony by which the infection is kept up in the individual.

According to Chagas the gamete providing for the exogenous cycle in the insect arises from certain trypanosomes which, lodging in the lungs, lose their flagella and, approximating their extremities, form a ring, and then a sphere in which the nucleus divides, giving rise to eight daughter spheres. These elongate and, escaping, enter the red blood-corpuscles and become male and female trypanosomes, thus providing for the exogenous cycle in the insect (Fig. 51).

In the insect the parasite is not transmitted hereditarily, but the nymph, as well as the mature lamus, is capable of harbouring and transmitting the parasite. In the endemic districts all the bugs and many domestic animals are infected. Chagas considers that the armadillo, whose burrows are haunts of lamus,

Lamus megistus. (*After Chagas.*)

PLATE III.

is the normal host of the parasite and a principal reservoir for the infection.*

Pathological anatomy.—Inflammatory and consequent degenerative changes, the result of the presence of the parasite, are in evidence in most of the affected organs. Under the microscope the cyst-like distended cells containing the parasite are to be found, particularly in the striated muscular fibres, and especially in those of the heart. The thyroid is enlarged, often sclerosed, with cystic cavities containing colloid material. The lymphatic glands and the spleen are also enlarged, the liver is fatty, serous effusions in pleura and peritoneum are common, and there may be evidences of meningo-encephalitis with infiltration about the vessels.

Prophylaxis.—This should be directed principally to the suppression of the insect concerned—*Lamus megistus* (Plate III.). It is a large black insect belonging to the family Reduviidæ, with numerous symmetrically arranged red markings; it is well known to the natives, who call it "barbeiro." The nymphs bite and can convey the infection, but the adults, having wings, are more dangerous. During the day-time they live in the grass walls and roofs of the dirty native houses, coming out after dark in search of their food—blood. Their habits indicate better and cleanlier housing, sleeping off the ground, and protection by mosquito-netting.

Treatment.—We know of no specific remedy. Arsenicals and antimony have failed in experimental animals. Treatment, therefore, must be on general lines.

Other Forms of Trypanosomiasis in Man

Seeing that most of the trypanosomes hitherto studied experimentally are capable of living in a variety of vertebrate hosts, it seems probable that other members of this group of parasites, in addition to *T. gambiense*, *T. rhodesiense*, and *T. cruzi*, may find in man at times a suitable host. Apparently

* Brumpt has recently observed development of *T. cruzi* in *Cimex lectularius* and *C. boueti*.

T. lewisi, *T. evansi*, and *T. brucei* do not thrive in man, but that circumstance does not warrant the inference that he is immune against all other species.

Certain of the Commoner Trypanosomes of Mammals

As the subject of trypanosomiasis in man is one of great and growing importance in tropical pathology, it is desirable that the student should have some practical acquaintance with the appearance and diagnosis of this type of parasite before he is called upon to deal with it in actual practice. I have thought it advisable, therefore, to give a short account of some of the corresponding infections of certain of the lower animals, such as, when the

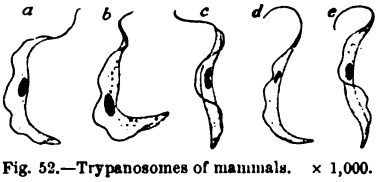


Fig. 52.—Trypanosomes of mammals. × 1,000.
a, T. equinum; *b*, T. brucei; *c*, T. equiperdum; *d*, T. lewisi; *e*, T. evansi.

opportunity offers, might supply him with the necessary material for study. If infected horses, oxen, dogs, etc., are not always available, the rat is to be met with everywhere, and can be relied on in most places to afford the student opportunities for acquiring much useful knowledge about trypanosomes, as well as experience in their microscopical diagnosis.

It must be remembered that *T. brucei*, *T. gambiense*, and *T. evansi* exhibit a wide range of pathogenicity for many species of animals.

Of the trypanosomes of mammals the best known and most important are the following (Fig. 52):—

T. lewisi (Kent, 1879) is a parasite of rats (*Mus decumanus*, *M. rattus*, *M. rufescens*). Similar parasites in hamsters, guineapigs, rabbits, etc., probably belong to different species; it has been held that *T. lewisi* is not capable of living in these animals, but subsequent work seems to contradict this.

On account of the facility with which it can be procured in most countries, *T. lewisi* offers the best opportunity for study

of the genus. In many places from 2 to 50 per cent. of the local rats harbour it, often in such abundance that, viewed through the microscope, the blood seems to seethe and quiver with the rapidly moving parasites. Specimens are easily procured by snipping off with scissors the tip of the rat's tail and dabbing the cut surface on the slip.

T. lewisi measures, on an average, including the flagellum, 24–25 μ by 1·5 μ; the posterior extremity is said to be more pointed than in the other known mammalian trypanosomes. The nucleus is situated in the anterior half or third of the body; the cytoplasm is very clear and free from granules. There is evidence that it is conveyed from rat to rat by the rat-louse and rat-fleas, which are now known to be its true alternative host. It is not, apparently, transmitted by the salivary glands of the insect, but multiplies in the hindgut of the flea, and, after assuming various crithidial forms, escapes in the excreta, and is thus inoculated into the wound made by the flea's proboscis.

In experimental rats it has been found possible to transmit infection to other rats through the unbroken skin by rubbing on cultures of this trypanosome.

It is generally held that *T. lewisi* is non-pathogenic. Certainly, infected rats usually exhibit a remarkable tolerance towards this parasite, but occasionally they do sicken and die.

The fact that the rat is susceptible to laboratory inoculation with the trypanosomes of man and cattle indicates the possibility of finding other species of trypanosomes in the blood of wild rats.

T. evansi (Steel, 1885); length, 22–30 μ; breadth, 1–2·5 μ. This parasite was discovered in 1880 by Griffith Evans in the Punjab, in the blood of horses suffering from surra, a disease which the natives of India ascribe to the bite of certain horse-flies (*Tabanidæ*). *T. evansi* is not limited to horses and mules, but attacks also camels, elephants, buffaloes, and dogs. Experimentally it has been transferred to monkeys, rabbits, rats, mice, and guineapigs; in nature, infection of dogs by feeding on animals dead of surra has frequently been observed. It has a very wide distribution in Southern Asia and in Malaya. It has been recently imported into Mauritius and the Philippines. We have no positive knowledge as to the definitive host or hosts of this trypanosome. Various blood-sucking flies belonging to the genera *Stomoxys*, *Hæmatobia*, and *Tabanus* have been incriminated. In Mauritius the epidemic is thought to have been spread by *Stomoxys nigra*.

The disease known as "Mbori," occurring among dromedaries coming from the Sahara into the Soudan (Timbuctoo, etc.), which is apparently also conveyed by a tabanus, is considered both by Vallée and Panisset, and by Laveran and Mesnil, to be a milder form of surra, the parasite which causes it being a "variety" of *T. evansi*.

T. brucei (*T. pecaudi*) (Plimmer and Bradford, 1899); length, 28–30 μ; breadth, 1·5–2·5 μ. The anterior extremity is

usually bluntly rounded. The cytoplasm often contains in the posterior half large, deeply staining granules. This parasite was discovered by Bruce in 1895 in the blood of horses suffering from nagana, the fly disease of Africa. The normal intermediary hosts of *T. brucei* are probably some of the African *Antelopidæ*, such as the wildebeest (*Catoblepas gnu*), the koodoo (*Strepsiceros capensis*), and the bushbuck (*Tragelaphus scriptus sylvaticus*), perhaps also buffaloes. Bruce's researches and experiments led to the belief that the disease was transmitted in a mechanical way by *Glossina morsitans*. Mr. Austen has shown that the tse-tse flies with which Bruce made his experiments belonged chiefly, if not entirely, to the species *G. pallidipes*, and now we know that other glossinæ, such as *G. fusca*, may also convey the disease, and that the rôle played by these flies is probably that of true alternative host. The development in the fly is identical with that described for *gambiense*. The fly does not become infective till the eighteenth, and remains so till the sixty-sixth day, or probably longer.

With the exception of man, and perhaps of certain strains of donkey and goat, all domesticated mammals hitherto experimented with, on inoculation with blood containing the parasite acquire nagana.

After inoculation of an animal with nagana blood, in from one to two days trypanosomes begin to appear in the blood, and persist therein till death, which, in the vast majority of species, is inevitable. In some species (rats, mice) the trypanosomes become very numerous; in others (the rabbit, guineapig) they are scanty and may be hard to find with the microscope, although their presence may readily be proved by the symptoms and by injection of the suspected blood into the rat. After inoculation death occurs in rats and mice in from two to three days, in rabbits in from five to twelve days, in guineapigs in about fifty days (extremes twenty to 183 days), in dogs in from twenty-two to twenty-six days, in monkeys in fifteen days, in horses and donkeys in from one week to three months, in goats and sheep in several months, and in cattle in from one week to six months, a proportion recovering. Thus resistance varies within wide limits.

In those animals in which death occurs within a few days of infection the parasites become very numerous, and, after one or two oscillations of temperature, death occurs suddenly. In those animals in which death is delayed a very striking cachexia is established. There is a chronic recurring fever, the numbers of parasites visible in the blood being greatest during the febrile accessions; there is also a peculiar firm œdema from infiltration of coagulable lymph into the connective tissue of the neck, abdomen, sheath of penis, genitals, and limbs; with intense anæmia, wasting, skin eruptions, and, often, blindness. On post-mortem examination the spleen is in most instances found to be enlarged, ecchymoses may be present in various viscera, and the lymphatic glands corresponding to the point of inoculation are swollen.

Other trypanosomes, more or less allied to *T. brucei*, and possibly representing only varieties of the same parasite, have been observed in German East Africa and Togoland among cattle, horses, and other animals. Again, the disease known as "aino," which occurs in Somaliland among dromedaries, and which Brumpt believes to be transmitted by *G. longipennis*, locally termed the "aino," is probably a variety of nagana.

T. equiperdum (*T. rougeti*), Dofl., 1901 length, 25-28 μ; breadth, $1\frac{1}{2}$-2 μ—differs from *T. brucei* in not having prominent granules in the cytoplasm. It is the cause of a peculiar disease in stallions, brood mares, and donkeys, occurring in South Europe, North Africa, Chile, and probably in the United States, and known as dourine or mal du coït. The latter name it has received from the fact that, as a rule, the infection is communicated through coitus. It is not yet certain whether the parasites have any alternate insect host into which they must pass at intervals in order to complete the life-cycle. Fleas have been suggested as possible intermediaries.

Symptoms appear in from ten to twenty days after infection. They begin in the case of the stallion with œdema of the sheath and some inflammation of the end of the penis and discharge from the urethra; in the mare there is a similar œdema of one or both labia and a muco-purulent vaginitis. Concurrently with increase of these symptoms œdema of the limbs and of the abdominal walls sets in, together with progressive anæmia, wasting, muscular weakness, flexion of the fetlocks, and skin eruptions. The appetite is preserved. Fever, except at the outset (40° C.), rarely exceeds 39° C. The disease continues for many months—four to ten. Before death weakness increases, the cornea may ulcerate, and there may be complete paraplegia from softening of the spinal cord.

The trypanosome of dourine occurs in the blood, but in numbers so scanty that to communicate the infection with certainty by this medium it may be necessary to inject from 10 to 15 c.c. Hence the improbability of infection by biting insects. On the other hand, it occurs in great abundance in the œdematous tissues, in the skin lesions, in the lymph, and in the discharge from the genitals.

In marked contrast with *T. brucei*, *T. equiperdum* is but feebly pathogenic to rats and mice, some of the former being quite refractory. In the rabbit and dog the disease resembles that in the horse, and is communicable by coitus. Monkeys, goats, sheep, and bovines are said to be insusceptible.

Although in many respects the parasites of dourine and nagana resemble each other, the differences in susceptibility of various animals as regards the two parasites indicate specific difference.

T. equinum (Voges, 1902); length, 22-55 μ; breadth, 1·5-2 μ. This parasite is clearly distinguished from the above-mentioned species by the very minute size of its blepharoplast. The cytoplasm contains granules, but not so numerous as in *T. brucei*. Its normal vertebrate host is probably the capy-

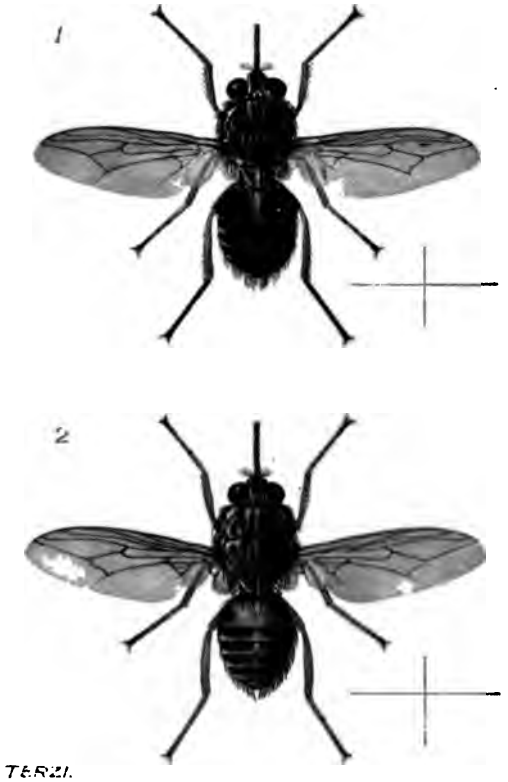
bara, *Hydrochærus capybara*, a large water mammal of South America belonging to the family *Caviidæ*. Nothing positive is known about its transmitting agent; *Stomoxys calcitrans* and *Stomoxys nebulosa* have been blamed. *T. equinum* causes in horses a deadly disease known as mal de caderas in Brazil, Argentina, and Central South America.

T. theileri.—Laveran (1902) reports the discovery by Theiler in the Transvaal of a trypanosome twice the size of any of the foregoing, and peculiar to cattle; so far, other domestic animals have been found to be immune. Theiler regarded it as producing an acute pernicious anæmia without poikilocytosis, and with only slight accompanying fever. He considers "that there exists a natural immunity in cattle against this trypanosome." Theiler believes that the transmitter of this parasite is a spider-fly, *Hippobosca rufipes*. Another species, *H. maculata*, recently imported with cavalry from India, is believed to be aiding in spreading the parasite. The disease is known as "galziekte," or bile-sickness, in the Transvaal. More recently, however, Theiler has altered his views, and now believes the disease to be due to a small piroplasm, *Anaplasma marginale*.

THE TSE-TSE FLIES (Plate IV.)

(Genus *Glossina*, Wiedemann, 1830)

The *Glossinæ* are sombre-coloured, narrow-bodied flies from about 8 to 12 mm. long, with a thick proboscis (i.e. proboscis enclosed by the palpi) projecting horizontally in front of the head. Their wings are large, of a brownish hue, and present a characteristic venation (Plate IV.) somewhat resembling that of the warble-fly (*Hypoderma*). The most striking peculiarity in the wing is the course of the fourth longitudinal vein, which about the middle of the wing bends abruptly upwards to meet the short and very oblique anterior transverse vein; here, describing a right angle, it runs obliquely downwards to meet the posterior transverse vein, and then turns upwards to reach the margin of the wing near the apex. When the tse-tse is at rest its wings overlap on the back, crossing each other like the blades of a pair of scissors. This resting attitude of the wings, besides giving the fly a peculiar elongated appearance, renders it readily distinguishable from those other blood-sucking diptera with which it might be confounded, such as the stinging-fly (*Stomoxys*) and the cleg (*Hæmatopota*). *Stomoxys* is smaller in size, has a slender proboscis, and its wings diverge at an angle when resting. *Hæmatopota* presents long, prominent antennæ and its wings are tectiform, i.e. they meet together at the base like the roof of a house and diverge slightly at the tips. In some species the abdomen is crossed by sharply defined dark brown stripes, interrupted at the middle line. In the males, beneath the end of the abdomen, the external genitalia form a conspicuous knob-like protuberance, which renders the sexes easily distinguishable.



Tse-tse flies.

1, Glossina palpalis; 2, G. morsitans.

PLATE IV.

The palpi are long, deeply grooved on their inner sides and closely applied to the proboscis, which they almost entirely conceal, the only uncovered portion being a peculiar large bulb-like expansion at the base. The proboscis consists of three parts (Fig. 54), *labrum*, *hypopharynx*, and *labium*.

The genus *Glossina* belongs to the sub-family MUSCINÆ, of the family MUSCIDÆ. The nearest related genera are *Stomoxys*, *Lyperiosa*, *Hæmatobia*, *Beccarimyia*; but on account of its limitation to Africa, its peculiar structural features (bulb at the basis of proboscis, remarkable male genitalia, characteristic venation of wings), and its aberrant mode of reproduction, it presents a marked individuality.*

The genus at present comprises fourteen species, though this number must not be considered final, as new species are discovered from time to time. Austen arranges the genus into four groups. (*See* the Table on p. 196.)

Distribution.—Tse-tse flies are confined to Africa. Some species, such as *G. fusca* and *G. morsitans*, have a very wide range throughout the greater part of intertropical Africa. *G. palpalis* is also widely distributed, ranging from the Senegal to Angola on the west, and throughout the Lualaba-Congo system to the Victoria Nyanza, Tanganyika, and Upper Nile at least as far north as Moolo in the Soudan. *Glossina morsitans* ranges south in Bechuanaland, North-Eastern Transvaal, and Zululand. *G. longipalpis* ranges through West Africa as far south-west as the Senegal and south to the Katanga district on the Congo. *G. pallidipes* is found throughout East Africa from Zululand to the northern boundary of East Africa. Other species appear to be more restricted. *G. longipennis* is found in Somaliland and adjacent regions; *G. tachinoides* has a wide range in West Africa; *G. pallicera* ranges to the Ivory Coast; *G. fusca* ranges from Sierra Leone to Uganda; *G. brevipalpis* is common in South, Central, and East Africa; *G. calligena* is found in Southern Nigeria. Knowledge of their topographical distribution is an important matter. The *Glossinæ* are never found on mountains; they are seldom seen above 3,000 feet; they are absent from extensive plains or other open places; they are rarely found in close cultivation. Their habitat is always in the neighbourhood of open water —along the banks of rivers, brooks, and springs, round the coasts of lakes, on low riverine islands, in swamps and mires, with open pools and sandy banks, especially at the foot of mountains. A sudd-covered or sedgy-banked river or lake

* Professor Newstead has (1912) adopted a classification of species of glossina based on a study of the male genitalia, which in this genus are characteristic. If macerated in potash the hypopygium can be turned backwards so as to display various complicated structures, namely, the superior claspers, the editum, the inferior claspers, the harpes, the juxta or penis sheath, the median process, and the connecting membrane. All these vary in shape in different groups; the median process and connecting membrane are found only in some of them.

GENUS GLOSSINA

- Hind tarsi not entirely dark brown or blackish brown
  - Upper surface of abdomen distinctly banded, consisting of *incomplete* transverse bands
    - Wings fairly dark, palpi long and slender — **4. Glossina fusca Group**
    - Wings pale, palpi short — **3. Glossina brevipalpis Group**
  - Upper surface of abdomen not consisting of interrupted dark bands — **2. Glossina morsitans Group**
- Third tarsi entirely dark brown or blackish brown (all joints more or less dark)
  - Dorsum of abdomen not so banded
    - 3rd joint of antennæ entirely dark, fringe of long fine hair
      - Dorsal surface of abdomen blackish-brown, hypopygium of ♂ grey . — *G. palpalis.*
      - Dorsal surface of abdomen dark brown, hypopygium of ♂ buff . . — *G. caliginea.*
    - 3rd joint of antennæ pale, clothed with long fine hair — *G. pallicera.*
  - Dorsum of abdomen buff, 3rd and other segments exhibiting interrupted transverse bands — *G. tachinoides.*

1. Glossina palpalis Group

- Dorsal surface of thorax with 4 oval dark spots — *G. longipennis.*
- Dorsal surface of thorax without such spots
  - Wings with upper and thickened portion of transverse vein dark in colour — *G. brevipalpis.*
  - Wings with upper and thickened portion of transverse vein not darker than adjacent veins . — *G. mediocrana.*

3. Glossina brevipalpis Group

- Last two joints of front and middle tarsi entirely pale . — *G. pallidipes.*
- Third joint of antennæ with a distinct fringe of hair . — *G. longipalpis.*
- Third joint of antennæ without a distinct fringe of hair . — *G. morsitans.*

2. Glossina morsitans Group

- Longest hairs in fringe on anterior margin of 3rd joint of antennæ equal to 3rd width of 3rd joint; palpi of moderate length — *G. tabaniformis.*
- Longest hairs on front margin of 3rd joint of antennæ; palpi long and slender . . — *G. nigrofusca.*

4. Glossina fusca Group

- Pleuræ drab-grey or isabella, hind coxæ buff . . . — *G. fusca.*
- Pleuræ dark grey, hind coxæ mouse-grey . . . — *G. fuscipleura.*

shore or sedgy swamp they do not frequent. They are most numerous along the water's edge; they become scarcer and scarcer as one advances inland, and disappear entirely within a few miles of the water. The places they occupy are sharply defined and, as a rule, permanently established. These places or stations are called "fly belts," and the natives know the limits of these belts precisely. The fly belts vary greatly in disposition and extent. Not infrequently they occur on one side of a stream but not on the other. These fly patches are usually confined to strips of jungle, to banana grounds coming down to the water's edge, or to areas of mosani or mimosa forest. In short, the essential condition of a tse-tse station are—the presence of open water, a wooded district, and a loose soil. As a rule, the fly patches are in sandy ridges or where there are overhanging or jungle-shaded banks.

The limitation of the tse-tse to definite tracts or "belts" has given rise to much speculation. The prevalent opinion is that the fly waits near water to feed on the animals that come to drink. Austen ascribes it to a characteristic social tendency which is exhibited very frequently amongst Diptera. Sambon suggests that it may be related to some food habit —possibly to a connection with air-breathing fish, of which there are several genera (*Clarias*, *Clarialabes*, *Channallabes*) with numerous species in the rivers and lakes of Africa; the fly either feeding directly on the fish or on some mammal or bird which feeds on these fish. Such an association with air-breathing fish might explain the peculiar patchy distribution of certain species of tse-tse fly, their limitation to the neighbourhood of water, and the sandy and thickly wooded nature of their haunts. In the dry season the air-breathing fish are obliged to bury themselves in the mud or to excavate burrows from which they come out towards evening in quest of food; they must therefore necessarily congregate in such places as offer conditions suitable to these habits.* It is very important to ascertain the exact reason for the singular topical limitation of the fly, for it may be that through knowledge of this the prophylaxis of fly-transmitted disease could get its opportunity.

Reproduction.—The *Glossinæ* do not lay eggs as do the majority of the Diptera, but, as in the case of forest-flies (*Hippoboscidæ*), the eggs hatch, and the larvæ feed, develop, and moult within the body of the parent, so that when extruded they have practically reached the pupa stage. In fact, the extruded larva becomes almost immediately a pupa, the larva skin becoming a dark, rigid puparium. When extruded, the fully grown larva is nearly as large as the abdomen of the mother; it is a yellowish ovoid body composed of twelve segments and presenting two small hooks at the anterior pole,

* It is interesting to note in connection with this suggestion that trypanosomes of the mammalian type have been found by Dutton, Todd, and Toby in *Clarias angolensis* at Leopoldville, and by Montel in another air-breathing fish of undetermined species.

and two protuberances at the posterior extremity, which is black. The perfect insect emerges from its pupa-case in about six weeks. In the case of *G. palpalis* the pupa has been found in Uganda buried in the loose earth about the roots of banana trees (Bagshawe) and similar situations.

Habits.—Tse-tse flies are voracious blood-suckers, exhibiting great persistency in their attacks on man and animals. They bite almost exclusively during the day. Contrary to what is the case among horse-flies (*Tabanidæ*) and mosquitoes (*Culicidæ*), of which the females alone suck blood, in the tse-tse both sexes are blood-sucking.

Fig. 53.
Tse-tse fly.

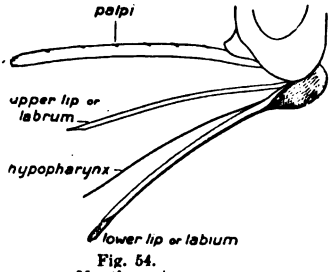


Fig. 54.
Mouth parts.

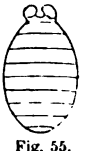


Fig. 55.
Pupa stage.

CHAPTER XI

LEISHMANIASIS

UNDER the term "leishmaniasis" three diseases are included, viz. kala-azar, oriental sore, and espundia. These diseases, though clinically quite distinct and having each a definite topical and geographical distribution, are all associated with what appears to be the same organism, *Leishmania*. But though these organisms appear to be morphologically identical, it is by no means justifiable to consider that they are specifically identical. The leishmania form is common to many protozoa; it is merely a stage—an immature stage—and until the life history is quite complete, and the natural history of the parasites of these diseases has been worked out, our judgment as to their identity or otherwise should be suspended. If it turn out to be the case that the germ causes of the various clinical forms of leishmaniasis are specifically identical, we shall have to conclude that the special pathogenic properties of these germs have been conferred on them during their extracorporeal life, especially by passage through particular animal intermediaries. Herein lies a wide field for future investigation.

I. KALA-AZAR

Synonyms.—Tropical splenomegaly, black sickness, Sirkari disease, Sahib's disease, Burdwan fever, kaladunkh, Dum-dum fever, ponos.

Definition.—An infective disease characterized by chronicity, irregular fever, enlargement of the spleen and often of the liver, the presence of the "Leishman body," *Leishmania donovani*, in these and other organs, emaciation, anæmia, frequently a peculiar hyper-pigmentation of the skin, and a high mortality.

History.—The earliest description of this disease

is by Clarke, who states, in the Assam Sanitary Report for 1882, that as far back as 1869 the attention of administrative officers in Assam had been directed to a peculiar disease called by the natives kala-azar, the ravages of which decimated, and in some instances almost depopulated, numerous districts in the Garo Hills. Notwithstanding its peculiar clinical features, its great fatality, its mode of spread along the lines of communication, the almost constant absence of malaria parasites from the blood, and the inefficacy of quinine treatment, until quite recently kala-azar was regarded by the majority of physicians as "a bad form of malaria."

In 1889 Giles, who had been appointed to investigate the etiology of kala-azar, denied its malarial nature, and stated that the disease was "neither more nor less than ankylostomiasis," because he found the ova of the hookworm in the fæces of practically all the cases he investigated. Giles's theory furnished a plausible explanation of the peculiar way in which kala-azar spread, and which could not be satisfactorily accounted for by the malaria theory. It was accepted by some, with the reservation, however, that he had underestimated the malarial element. Dobson strongly opposed the ankylostoma theory. He stated that in 116 cases of kala-azar he had found the hookworm in 75 per cent., in 212 cases of other illness he had found it in 73·20 per cent., and in 146 healthy men he had found it in 67·12 per cent.

In 1896 Leonard Rogers and in 1898 Ronald Ross were appointed to re-investigate the disease. Both agreed as to its malarial nature; the former regarding it as a malignant type of malaria, the latter as malarial disease to which some form of secondary infection was superadded.

In 1903 Bentley endeavoured to prove that kala-azar was a malignant form of Mediterranean fever, a disease which he suggested was probably introduced into India at the time of the Mutiny by British troops from Malta, Gibraltar, and other Mediterranean ports.

Owing to the absence of malaria parasites in the

cases of tropical splenomegaly I had studied in this country, the absence of tertian and quartan periodicity in the fever, and the uselessness of quinine in its treatment, I had come for some years to regard this disease as non-malarial and as one *sui generis*. In 1903, struck by certain features common to trypanosomiasis and kala-azar, I ventured to suggest in the third edition of this manual that the latter disease might be a trypanosoma disease.

A few months later, Leishman published a paper "On the Possibility of the Occurrence of Trypanosomiasis in India," wherein he stated that in 1900, at Netley Hospital, at the post-mortem of a soldier who had died of so-called Dum-dum fever, he had discovered in smear preparations from the spleen-pulp a number of small round or oval bodies, two or three microns in diameter, which, on being stained, presented besides the nucleus a smaller rod-like chromatin mass, set perpendicularly or at a tangent to the circumference of the larger nuclear mass. At the time he was unable to explain the nature of these bodies; but in May, 1903, on coming across similar bodies in the blood of a rat which had died of nagana and the blood of which during life contained numerous trypanosomes, he surmised that the bodies found in the soldier in 1900 represented degeneration forms of trypanosomes.

In July, 1903, Donovan stated that he had found similar bodies three months previously in smears of the spleen, taken post-mortem from cases said to have died from chronic malaria. On June 17th he found identical bodies in splenic blood taken during life from a patient suffering from irregular fever and enlarged spleen, and whose peripheral blood showed no malaria parasites. Identical bodies had also been found by Marchand in January, 1903, in sections of the spleen, liver, and bone marrow from a patient who had taken part in the Pekin campaign and had suffered from a long-continued irregular fever, extreme enlargement of the spleen, and anæmia.

In December, 1903, having under treatment a patient from Darjeeling suffering from typical kala-

azar, I had the opportunity of examining blood abstracted from his spleen on two occasions, and found it swarming with the peculiar bodies already described by Leishman, Donovan, and Marchand. I was able to show that these bodies were not endocorpuscular parasites, as suggested by Laveran and Mesnil, who had expressed the opinion that they belong to the genus *Babesia*.

Then followed observations by a number of investigators, and we learnt that kala-azar was a widely distributed, though hitherto unrecognized disease. It was found in various parts of the eastern side of India, in China, Arabia, the Soudan, Tunis, Sicily, Italy, Algeria, Crete, Spain, Portugal, Greece and the Grecian Archipelago,* the Caucasus, Central and South America, and South Africa, etc. Besides those of Leishman and of Donovan, amongst the most important papers on the subject are those of Christophers, who showed that the parasite attacks the endothelial cells; of Leonard Rogers, who in cultivating the parasite obtained a characteristic flagellated form; of Dr. J. H. Wright, of Boston, U.S.A., who found parasites morphologically indistinguishable from those of kala-azar in the granulation cells of tropical sore; of James, who confirmed and extended Wright's observation; of Patton, who considers he has discovered the extracorporeal developmental forms of the parasite in a species of bed bug; and of Nicolle and Comte on the occurrence of the same or a similar parasite in children and dogs in Tunis, and in kittens in Algiers.†

Epidemiology.—Our knowledge of the epidemiology of kala-azar is gathered mainly from the Assam epidemic, which began about 1870, when the disease appears to have been introduced from Rangpur.

* In the Ionian Islands and Greece the disease known as "ponos" was found by Gabbi to be infantile kala-azar.

† Nicolle gave the name *Leishmania infantum* to this variety of the parasite in order to call attention to the special liability of children to the infection in Mediterranean countries, and not because he considered it specifically distinct from the Indian form, which attacks adults and children indifferently.

Rogers believes that it was possibly a continuation of a similar epidemic, known as "Burdwan fever," which had been raging in Lower Bengal. The importation theory is supported by the names of "Sirkari disease" and "Sahib's disease" given by the Garos, who state that it was unknown among them until after the English took over their country The epidemic began almost simultaneously at Bengal Kutta and Karaibari, two places fifty miles apart but in direct communication with the Rangpur district. It advanced very slowly along the valley of the Brahmaputra, taking seven years to spread less than a hundred miles. Following the lines of intercourse, it attacked first the larger stations, and then spread to the smaller villages around. The introduction of the disease into a village was almost invariably traced to someone coming with the disease on him from an infected locality. Some isolated villages escaped in a remarkable manner. Whilst the disease spread up the valley, the invasion of new places was counterbalanced by its dying out in villages and districts which had previously suffered. Generally, it clung to a place for about six years, and then disappeared without any apparent change in the local conditions. A house appeared to retain the infection for many months; the natives considered that it could not be reoccupied with safety under one year. During the course of the epidemic kala-azar never extended far above the level of the Brahmaputra valley. The disease did not arise in the first instance in the interior of the Garo Hills district, as some authors affirmed, but appeared first at the foot of the hills, and then spread between them along the patches of low, flat, terai country.

On account of its deadliness, especially in the smaller villages, kala-azar as it swept onwards became a terror to the natives. Those suffering from the disease were turned out of the villages; sometimes they were made unconscious with drink, taken into the jungle, and burnt to death. Some villages cut off all communication with neighbouring villages for fear of infection; other villagers deserted

their homes and even migrated to a different district.

Although the foregoing is the only recorded example of kala-azar as a widespread and active epidemic, it had been recognized that a disease clinically identical occurred sporadically in several places in India and elsewhere. These cases had often been regarded as a form of malarial cachexia, but the identity of the sporadic and epidemic disease has now been established by the detection of the Leishman or Leishman-Donovan body in both.

Etiology.—The kala-azar parasite (Plate V.) has now been relegated to the genus *Leishmania*, Ross. We know two stages of this body, intracorporeal and extracorporeal. Possibly these represent

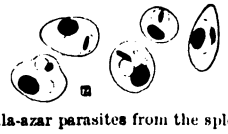


Fig. 56.—Kala-azar parasites from the spleen, stained.

respectively asexual and sexual forms; the former found in man and possibly in some other vertebrates, the latter obtained in artificial culture media, and, it may be, in certain insects—flies, bugs, fleas, lice, mosquitoes.

The distribution of the parasite within the body of man is very general. Apparently its special habitat is the endothelial cells of blood-vessels and lymphatics. It is particularly abundant in the spleen (Fig. 56), in the liver, and in the bone marrow; but it also occurs in the lung, in the kidney, in the mesenteric and other lymphatic glands, in petechiæ, in the arachnoid, in ulcers involving the intestinal mucosa, and in papules and ulcers of the skin. It occurs also in the blood, though in small numbers, being found there both in polymorphonuclear and mononuclear leucocytes, very rarely in the red corpuscles.* In

* When existing in the blood in small numbers their presence can, in the hands of experts, be demonstrated by the cultural method. Centrifugation of the blood is of little use.

Parasites of kala-azar and oriental sore.

KALA-AZAR: 1, Free forms from the spleen; 2 and 3, in the endothelial cells; 4, in the liver.

ORIENTAL SORE: 5, In endothelial cell; 6, free forms.

PLATE V.

the blood it is in greatest abundance towards the termination of the case, especially during fever, and when intestinal symptoms are present (Donovan).

The Leishman or Leishman-Donovan body, as it is generally called, is a small ovoid or roundish organism measuring from 2 to 4 μ in diameter. Stained according to Leishman's method, it shows two lilac-coloured chromatin masses, one larger than the other, enclosed in a cytoplasm which acquires a faint bluish tint about the periphery. The larger chromatin mass is the nucleus, which may be oval and centrally placed (resting stage), or elongated and at the periphery (pre-division stage). The smaller chromatin mass is the micronucleus or blepharoplast; it is usually in the shape of a short rod, and is placed perpendicularly, or at a tangent to the nucleus. It stains more deeply than the latter. The parasites multiply by simple fission, the division of the body being always preceded by the elongation and division of the nucleus and blepharoplast. The plane of division is always longitudinal. Some forms, having attained a larger size, suggest a process of multiple fission; these are almost circular, and present, as a rule, six chromatin masses, three large and three small, the former being placed round the periphery.

The parasites, as they occur in man, are probably almost invariably intracellular. They grow and multiply within the host cell, causing it to enlarge, and then, after disintegration of the nucleus, to disrupt. The parasites so set free either enter other endothelial cells or are taken up by the white blood-corpuscles, in which they are sometimes found in the peripheral circulation. In smear preparations they are often free or in clusters of various numbers, sometimes arranged with great regularity like the merozoites in the segmenting quartan or tertian malaria parasites. Sometimes as many as 50, or 200, or even more parasites are found together embedded in a structureless matrix or stroma, probably the remains of the original host cell.

In cultures (Fig. 57) the parasites enlarge very rapidly. They retain at first their shape, the cytoplasm

becoming granular, opaque, and vacuolated. Having attained a diameter of 7 to 9 μ, they assume an elongated pyriform shape and become flagellated. The flagellum arises from the blepharoplast at the rounded end of the parasite, and projects at once clear of the body as in *Euglena*. There is never an undulating membrane as in trypanosomes. These flagellated forms measure from 12 to 20 μ in length. They multiply by longitudinal fission; sometimes throwing off exceedingly fine linear forms (Leishman), comparable in their delicacy to spirochætes. They move actively with the flagellum in front, and towards the

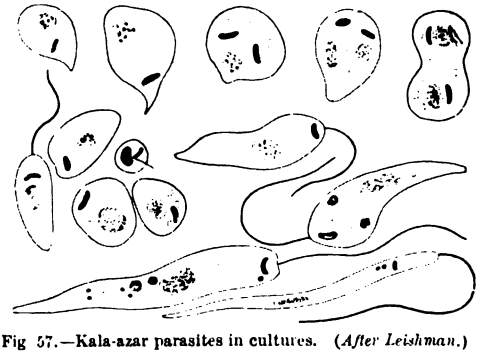


Fig 57.—Kala-azar parasites in cultures. (*After Leishman.*)

twelfth day tend to agglomerate in rosette groups, the flagella being directed centrally.

The culture medium used by Rogers was blood to which a small quantity of sterile, slightly acid citrate of soda solution was added to prevent coagulation. When the culture medium was kept at blood heat the parasites very rapidly degenerated and disappeared; but when placed in an incubator at 27° C. they lived for three or four days and multiplied. A lower temperature was found to be even more suitable. When temperature was lowered to 20°–22° C. the parasites multiplied more readily, acquired a considerable size, and finally assumed the elongated, motile, flagellated form. The N.N.N. culture medium (p. 156) gives excellent results, and in this, by trans-

planting at intervals of from twelve to fifteen days, the cultures can be kept alive up to at least four years. The presence of moulds does not affect the cultures, but bacterial contamination is fatal.

Animal experiments.—The early attempts in India to communicate kala-azar to the lower animals failed, but Nicolle in Tunis, and, subsequently, many others elsewhere, have shown that dogs, cats, jackals, monkeys, rats, mice, and to a less extent guineapigs and rabbits, are inoculable, provided large doses of the virus are injected into the liver or peritoneal cavity. For a dog, 2 to 4 c.c. of a thick emulsion in normal saline of infected liver, spleen, or bone marrow usually suffices. Intravenous injection is not so successful. Injection of cultures sometimes succeeds.

Mode of transmission.—This has not been definitely ascertained as regards India, but there is evidence that the dog* is the principal reservoir of the disease. It has also been asserted, but not proved, that the dog fleas, *Pulex serraticeps* and *Ctenocephalus canis*, are the transmitters in the endemic areas in and around the Mediterranean. So far as ascertained, wherever kala-azar occurs in man—principally children—in the Mediterranean basin the dogs are infected with *L. donovani* in variable proportion from 1·8 per cent. to 81 per cent., though Donovan has failed to find, except in a negligible proportion of instances, naturally infected dogs in India. Strange to say, although the dog has been found to be liable to the infection in the Mediterranean area, in India it seems to be partially immune and only contracts the disease after massive intraperitoneal injections of Leishmania-infected organs.

The exact way in which the flea transmits the virus, if it be the transmitting agent, is not known—whether the parasite undergoes important biological changes in the insect, or whether the latter functions merely in a passive or mechanical way.

Patton has put forward a claim for the bug as the

* In the naturally infected dog symptoms resembling rabies have been noted, by Nicolle, associated with the presence of Leishmania in the spinal cord.

transmitter of Indian kala-azar. It may be so, but conclusive proof has not been adduced. Should the conjecture be confirmed it would afford an explanation of the tendency the disease is known to have to cling to particular localities and houses, and it would supply a valuable guide to prophylaxis.*

Under natural conditions kala-azar, like other diseases caused by similar protozoal organisms, is probably transmitted by a living agent. There are certain facts, however, which tend to suggest that the carrier need not necessarily be a blood-sucking animal. In the first place, the parasite in man is not in great abundance in the peripheral circulation. Secondly, the parasite is often present in ulcerations of the skin and of the intestinal mucosa, suggesting elimination by these organs. Thirdly, we know that although some species of *Herpetomonas* are fostered by blood-sucking flies, such as *Tabanus* and *Hæmatopota*, others are found in non-biting forms, such as *Musca*, *Sarcophaga*, *Pollenia*, and *Fucellia*, which could become infected only by settling on ulcerations or on fæcal matter. It is conceivable that such insects might transmit the infection of kala-azar by depositing the parasites on wounds and abraded surfaces.

Predisposing causes. — Kala-azar attacks both sexes and all ages, but, *unlike malaria*, it shows a predilection for the acclimatized—the natives; in them it is said to be as severe and fatal as in the case of new-comers. In the Mediterranean basin it occurs almost though not quite exclusively in children (five months and upwards); in India it occurs at any age. The reason for this discrepancy as regards age has not been explained.

Incubation period.—This is difficult to fix. In the case of one Englishman, recently under my care, the time that elapsed from his arrival in perfect health in the endemic region and the onset of the fever which terminated in kala-azar (diagnosed

* The discovery of a flagellated organism or of developing Leishmania in the gut of an insect must not be regarded as adequate proof that the insect is the normal, or even a transmitter of the organism concerned.

microscopically both before and after death) was under ten days. In a proportion of instances, as in some artificially infected dogs, and as is the case in dermal leishmaniasis, the disease may remain latent for months. In fatal cases in man the parasite may disappear from the tissues before death; what appears to be an explanation of this curious fact has lately been advanced by Archibald, who found certain coccoid bodies by hepatic puncture in these latent cases; he believes that these bodies represent a stage of the parasite.

Symptoms.—Bentley, speaking from a large experience in Assam, and with full knowledge of the literature of epidemic kala-azar, says that the disease commences with high fever, which may be preceded by rigor and, in some cases, by vomiting. This initial fever—intermittent in some instances, more frequently remittent—may be very severe. It lasts for from two to six weeks, occasionally longer. During its progress the spleen and liver enlarge, increasing and decreasing at first, often in a most remarkable degree, in harmony with the fluctuations of the fever. Then comes a period of apyrexia and general improvement, to be followed once more by fever and splenic and hepatic enlargement, and perhaps tenderness. In this way spells of fever and apyrexia recur for months, absolutely unchecked by quinine or other drugs, until finally a low form of fever, rarely over 102° F., becomes more or less persistent. Profuse sweats are common during remissions at all stages of the fever; rigor is rare. Pains in the limbs often suggest rheumatism. When the disease is thoroughly established emaciation and anæmia become noticeable, and, together with the enlargement of the liver and spleen, cause the patient to present a typical appearance. Œdema of the legs, sometimes circumscribed œdemas, or even ascites may now be present. In many the skin acquires an extraordinary earthy-grey colour; the hair is apt to become dull, dry, and brittle, and may fall out; petechiæ, in the axillæ especially, are not unusual; epistaxis and bleeding from the gums are common. This condition

of chronic fever, enlargement of spleen and liver, emaciation and anæmia, may continue for months, or even one or two years, until improvement sets in, or, more usually—96 per cent. of cases (Rogers)—until the patient is cut off by intercurrent disease, especially dysentery (90 per cent.), occasionally phthisis, pneumonia, cancrum oris, or asthenia.

According to Rogers, the degree of anæmia, in uncomplicated cases, is usually only a moderate one, the number of red corpuscles being not infrequently over 4,000,000, and, as a rule, over 2,500,000 even in advanced cases. The most remarkable change in the blood is the great and constant reduction in the number of leucocytes. Instead of there being 1 white to about 625 red, as in a normal subject, the proportion is commonly from 1 to 2,000 to 1 to 4,000, and may be lower still. The reduction is most marked amongst the polynuclear variety; the lymphocytes and large mononuclear leucocytes, although greatly reduced in number, show a relatively increased percentage as in some other protozoal diseases.

In those cases which I have had an opportunity of carefully watching I have been struck with the fact that, notwithstanding the chronic fever and progressive wasting, throughout the long illness the tongue has been almost uniformly clean and the appetite and digestion good.

Morbid anatomy.—The *spleen* is greatly enlarged and the thickened capsule may show signs of perisplenitis. The trabeculæ are enlarged, the pulp increased in bulk and full of blood. A section or smear preparation, appropriately stained, will show prodigious profusion of parasitic growth in the crowds of the large mononuclear cells already referred to. The *liver* also is generally much enlarged. It has a brown or mottled section. The parasites are in great abundance, occupying large mononuclear cells, attached or free, in the dilated hepatic and portal capillaries. There may be some cirrhotic changes, but the hepatic cells, though atrophied and perhaps fatty, never contain parasites. The *bone-marrow* is

similarly packed with parasite-laden cells. *Intestinal ulceration* is very common, and parasites may be found in the walls of the ulcers as well as in *skin ulcerations* or in the *lymphatic glands*. Occasionally they are found in connection with the blood-vessels in the *kidneys*, but never in the epithelium of the secreting tubules.

Diagnosis.—Irregular chronic fever with enlargement of the spleen and a relative mononuclear leucocytosis in patients from the endemic zone suggests kala-azar. An examination of the blood can at once exclude leucocythæmia and, if taken together with absence of tertian or quartan periodicity and the inefficacy of quinine, malaria. Trypanosomiasis and kala-azar may be difficult to distinguish between, and unless their respective parasites are detected a positive diagnosis is impossible, although geographical considerations and subsidiary skin and lymphatic lesions may assist in forming an opinion.

Banti's disease clinically approaches very closely, and can only be excluded by a microscopical examination of the liver and spleen juices, or of the blood. Similarly, malignant disease of the abdomen, so often associated with irregular chronic fever, in the absence of a satisfactory microscopical examination of liver or spleen juice, may be difficult to distinguish from kala-azar.

On the discovery of the germ cause of kala-azar, and the fact that this disease is widely distributed throughout the tropics and sub-tropics, there was at first a tendency to regard all cases of febrile tropical splenomegaly which are not associated with malaria, trypanosomiasis, and other well-known conditions, as kala-azar. Further observation and experience have considerably modified this view, since it has been found that a proportion of such cases do not show the Leishman body either during life or after death. Possibly other protozoal germs, as yet unrecognized, are responsible for some of these cases. So that, in any given case of tropical splenomegaly, until the Leishman body is found it would be rash to pronounce a positive diagnosis of kala-azar.

The discovery of the Leishman body in the blood, lymph, or tissues, therefore, is the only reliable indication of kala-azar. In the first instance it should be sought for in the blood, or in material obtained by puncture of lymphatic glands, after appropriate staining. A high-power immersion lens is indispensable, and every leucocyte or scrap of tissue must be carefully scrutinized for the little oval body with the round or oval nucleus and rod-shaped blepharoplast. Several films, especially at the edges of the preparations, must be searched in this way before recourse is had to splenic or, better as being less dangerous, hepatic puncture.

Splenic puncture must not be lightly undertaken. A preliminary examination of the blood should always be made, not only with a view to ascertain the presence of the Leishman body, but to exclude leucocythæmia and obviate the necessity for splenic puncture, and the attendant risk of fatal hæmorrhage so easily induced in that disease. Death from hæmorrhage has frequently followed this seemingly trivial procedure. When the liver is enlarged, being a less vascular organ and less easily torn, it should be selected for punctures in preference to the spleen. The abdomen had better be fixed firmly with a binder to prevent as far as possible movement of the diaphragm and consequent risk of tearing the punctured organ. A fine hypodermic needle, scrupulously clean and dry,* should be used, the patient being directed not to start or breathe while the puncture is being made. Failure to draw blood is not to be regarded as failure to obtain material for microscopical examination; on the contrary, it is an advantage, as the object is to procure spleen or liver pulp, not blood. After blowing out the contents of the needle on a slip, a film should be spread and, after it has dried, stained by Leishman's or Giemsa's procedure, and then examined with a twelfth objective. The parasite is easily recognized by its size, shape, and two chromatin masses.

* The presence of water in the needle will distort or burst the parasite and render it unrecognizable.

Treatment.—This, as a rule, is most unsatisfactory. Intercurrent malarial attacks may be treated with advantage with quinine, but for the disease itself this drug, even in huge doses and persisted with for long periods, is useless, if not harmful. Arsenic has proved equally unsatisfactory. Intravenous injections of salvarsan have been followed by favourable results. Splenectomy has been tried, but has failed. I have treated four cases with intramuscular injections of atoxyl. In two of these there was no improvement, the disease running its usual fatal course; but in the other two cases recovery ensued, whether as a result of the treatment or not I cannot assert. The atoxyl should be given as for trypanosomiasis, best, according to my experience in Europeans, in 3-gr. doses every three days, and persevered with for a year or longer. The expulsion of intestinal parasites, change to a healthy climate, good food, warmth, rest, physical comfort, and good hygienic conditions are indicated.

It is now realized that in children a mild form of the disease exists, and that spontaneous recovery is possible though rare.

Prophylaxis.—Having regard to the character of the disease, in the endemic districts the cases should be dealt with as infectious; they should be isolated, and their houses and fomites should be disinfected or burnt. Domestic and personal cleanliness is of great importance. Infected dogs and cats should be destroyed; and as far as possible, in the endemic districts, dogs should be kept free from fleas and not in too close association with man.

Oriental sore and kala-azar.—If the parasite of oriental sore be specifically identical with that of kala-azar, it must somehow have been deprived of its virulence; for, although kala-azar is a fatal disease, oriental sore is eminently benign. It is known that one attack of oriental sore confers immunity against further attacks of the same disease. It affects dogs and other animals. May it not be that the virulence of the Leishman body is removed by passage through some animal other than man; or, possibly, by being

transmitted by some intermediary other than that which transmits the virulent kala-azar? If this be so, we have at hand a vaccine against kala-azar. The idea is worth testing: "Are those who have had oriental sore immune as regards kala-azar, and vice versa?" * In support of this suggestion it has long been recognized in India that in districts where kala-azar is common oriental sore is rare. Recent work has shown that this is partially true for the Mediterranean area also. In Teheran the dogs are found infected with dermal leishmaniasis, and a general infection combined with cutaneous lesions has been produced in mice by intravenous injections of cultures of *Leishmania tropica* (the parasite of oriental sore), and sores in monkeys by cutaneous inoculation of cultures of *Leishmania donovani*.

II. Oriental Sore

Synonyms.—Tropical sore, bouton d'Orient, Delhi boil, etc.

Definition.—A specific ulcerating granuloma of the skin, endemic within certain limited areas in many warm countries. It is caused by a species of Leishmania, and is characterized by an initial papule, which, after scaling and crusting over, generally breaks down into a slowly extending and very indolent ulcer. Healing after many months, it leaves a depressed scar. The sore is inoculable and, usually, protective against recurrence.

Geographical and seasonal distribution.—Among the endemic places may be named Morocco, the Sahara (Biskra, Gafsa), the Niger, Egypt, Crete, Cyprus, Asia Minor, Syria (Aleppo), Mesopotamia (Bagdad), Arabia, Persia, the Caucasus, Turkestan, India (Lahore, Multan, Delhi, etc.). Juliano describes the disease as being common in Bahia, Brazil, and cases are reported from Bolivia, Peru, Panama, and French Guiana—where it is called "pian bois,"

* Nicolle has succeeded in producing a certain amount of immunity in dogs and monkeys to oriental sore and to kala-azar by injecting them intraperitoneally with cultures and infected material containing the Leishmania of the local and of the general disease.

"bosch-yaws," etc. The name oriental sore, suggested by Tilbury Fox, is therefore no longer quite appropriate.

Locally, oriental sore is often called after some town or district in which it is specially prevalent; thus we have Delhi boil, Bagdad boil, "clou de Gafsa," and so forth. It is much more common in cities than in the country. In Bagdad few escape an attack; visitors, even of a few days only, are almost certain, at particular times of the year, to contract it.

According to Hirsch, in the tropics this form of ulceration is especially prevalent about the commencement of the cool season; in more temperate climates, towards the end of summer or beginning of autumn. Years of prevalence may be succeeded by years of comparative rarity; possibly in harmony with altered sanitary conditions. In Delhi, for example, in 1864 from 40 to 70 per cent. of the resident Europeans were affected with the local sore; on certain sanitary improvements being effected, the frequency of the disease was immediately materially reduced.

Histology; etiology.—Section of the papule displays an infiltration of the derma by a mass of small round granulation cells. These lie between the elements of the tissues, particularly about blood-vessels, lymphatics, and sweat-glands; towards the centre of the lesion they completely replace the normal structures. Various micro-organisms have been described in association with oriental sore. By staining sections in gentian violet and afterwards partly decolorizing in spirit, Cunningham and Firth found certain violet-stained bodies (*Helcosoma tropicum*), varying in size and grouping, in a proportion of the infiltrating cells. These bodies Cunningham was inclined to regard as parasites. Riehl looked upon them as the result of a hyaline degeneration of protoplasm, and advanced a claim for certain micrococci which he said he found in great profusion in the granulation cells. That Cunningham's view is correct was proved by an American observer, H.

Wright, who, in 1903, found in the granulation cells of an oriental sore the Leishman body (Cunningham's parasites) in great profusion. This observation has been abundantly confirmed in India and elsewhere; so that it may now be considered as definitely established that the cause of oriental sore is the Leishman body, or a body morphologically identical with this parasite. For the characters of the Leishman body, *see* p. 205 and Plate V.

The cultivation of the parasite, first carried out by Nicolle, is easily effected in the N.N.N. medium. The surface of a non-ulcerating sore is first painted with iodine and then punctured with a fine syringe. The parasites, as in the case of *L. donovani*, grow best in the condensation water. Inoculation of cultures has given rise to lesions in monkeys.

In what way, under natural conditions, the parasite enters the tissues it is as yet impossible to state definitely. Not improbably it is conveyed by flies or other biting insects, and by them either inserted into the skin or applied to some pre-existing wound or sore. Dogs in Teheran, and perhaps camels, are subject to this or a similar disease. Monkeys and dogs have proved to be experimentally inoculable, while donkeys, horses, goats, and sheep are refractory. It must not be overlooked that in susceptible animals an important source of infection may lie.

Probably there are two methods of infection—(*a*) *direct*, the Leishman body being directly inoculated without undergoing sexual or other developmental change; (*b*) *indirect*, in which an infected fly, bug, or other insect, either itself or through its progeny, conveys to the new host the parasite which in the meantime has undergone evolutionary changes.* Wenyon has proved that the parasite is unable to enter through the unbroken skin.

* Patton has definitely stated that the bed bug, *Cimex rotundatus*, is the transmitter of the disease in Cambay, India: these results Wenyon has failed to confirm. It is a mistake to conclude, because a parasite is capable of living for a time and even developing in the alimentary canal of some blood-sucking insect, that that insect is the natural transmitter of the disease. Wenyon has found developing Leishmania from oriental sores in the stomach of mosquitoes.

As a rule, second attacks do not occur. Observing this, the Jews of Bagdad at one time practised on their young children oriental-sore inoculation.

Neither race, nor sex, nor age, nor occupation, nor social condition materially influences susceptibility.

Incubation period and constitutional symptoms.—The incubation period of oriental sore is variously stated in days, weeks, or months. That it may be a brief one, a few days or weeks, seems to be established by the appearance of the sore within a short time of arrival in endemic districts, or after inoculation. That it can be of much longer duration is equally certain. I have seen an unquestionable oriental sore which did not appear until five months after the patient had been exposed to any possibility of infection. Wenyon inoculated himself with oriental sore in Aleppo; it was not until six and a half months later that a Leishmania-containing papule subsequently developing into a sore appeared at the site of inoculation. In other cases the incubation period has been as much as fifteen months, or even longer.

There is very little reliable information about the presence or absence of constitutional symptoms. It is customary to describe the disease as non-febrile. This may be true in most cases, but I am not convinced that it is so in every case. It is obvious that in a disease with, at least in some instances, a very prolonged incubation period, slight or even severe fever might be overlooked or misinterpreted. Oriental sore produces an immunity against itself. There must, therefore, be profound constitutional change. In other diseases attended with similar change fever is almost invariably present at one time or another in their course. In the case just alluded to as occurring in my experience, a severe anomalous fever, of five or six weeks' duration, preceded by eight months the appearance of the local lesions. In Wenyon's case the development of the initial papule was preceded by smart fever supposed at the time to be influenzal. Seeing, as has been pointed out (p. 214), the close connection of oriental sore with kala-azar, this question of the constitutional

symptoms in the milder disease is an important one, and should be carefully studied.

Symptoms.—The local lesion in oriental sore commences as a minute, itching papule which tends

Fig. 58.—Oriental sore. (*After Wenyon. From photo by R. McKay, reproduced in Journ. Lond. School Trop. Med.*)

to expand somewhat as a shotty, congested infiltration of the derma. After a few days or weeks the surface of the papule becomes covered with fine, papery scales. At first these scales are dry and white; later they are moister, thicker, browner, and

adherent. In this way a crust is formed, which on falling off, or on being scratched off, uncovers a shallow ulcer (Fig. 58). The sore now slowly extends, discharging a scanty ichorous material; this from time to time may become inspissated and crust over, the sore continuing to spread underneath. The ulcer extends by the erosion of its perpendicular, sharp-cut, and jagged edge, which is surrounded by an areola of congestion. Subsidiary sores may arise around the parent ulcer, into which they ultimately merge. These sores, usually about an inch in diameter, may come, in some instances, to occupy an area several inches across.

After a variable period, ranging from two or three to twelve or even more months, healing sets in. Granulation is slow and frequently interrupted. Often it commences at the centre whilst the ulcer may be still extending at the edge; often it is effected under a crust. Ultimately a depressed white or pinkish cicatrix is formed. Contraction of the scar, particularly if it happens to be on the face, may cause considerable and unsightly deformity.

Oriental sore may be single or multiple. Two or three sores are not uncommon; in rare instances as many as forty have been counted on the same patient. They are mostly situated on uncovered parts—hands, feet, arms, legs, and, especially in young children, on the face; rarely on the trunk; never on the palms, soles, or hairy scalp. Seidelin, Darling, and Connor have described as occurring in South America oriental sores with a predilection for the margins of the ears.

Dr. Sturrock, who practised in Bagdad for four years, informs me that in rare instances the disease recurs more than once, but, as a rule, the sores of the second attack do not break down. He has also seen a chronic type of the disease, which may recur and persist for several years and be associated with deposit in the testes, in mucous membranes—such as the urethra and mouth—as well as with a chronic form of dactylitis.

In a very few instances the initial papule does not proceed to ulceration, but persists as a scaling

or scabbing, non-ulcerating, flattened plaque—just as sometimes happens in the case of the primary chancre of syphilis. Sometimes the ulcer is quite superficial, an erosion rather than an ulcer. Occasionally, from contamination with the virus of some other infectious acute inflammatory skin disease, the primary lesion may become complicated, and perhaps a source of serious danger. Otherwise, oriental sore is troublesome and unsightly rather than painful or dangerous.

According to Nattan-Larrier there is a mononuclear leucocytosis in this form of leishmaniasis similar to that in kala-azar.

Treatment.—Some have advocated destruction of the primary papule, and even of the ulcer, by caustics or by the actual cautery; but a knowledge of the nature and natural progress of the disease suggests a protective and soothing rather than an irritating line of treatment. A dressing with some mild antiseptic ointment, as of iodoform, boric or salicylic acid, is indicated. Favourable results are reported from the application of an ointment consisting of equal parts of lanoline, vaseline, and methylene blue. Recently Row seems to have had prompt cures from hypodermic injections of killed cultures of the Leishmania parasite. The dose of a rich culture on N.N.N. medium, to which 5 drops of glycerine had been added forty minutes before, was $\frac{3}{8}$ c.c. This may be repeated a few days later. Dr. Andrew Duncan informed me that in India he had seen these sores treated with great success by bandaging over them a piece of thin sheet-lead. Most probably these were not true oriental sores, which, as analogy would lead us to think, could heal only as the result of a specific treatment or on the establishment of immunity. X-ray and light treatment have been tried, with success in some cases, and unfavourable results in others. The reports on radium, salvarsan, and CO_2 snow treatment are decidedly favourable. Tonics when the patient is anæmic or debilitated, attention to the general health, change of climate should the disease persist beyond the usual time, are indicated.

III. Espundia

Under the term espundia, bubas braziliana, or uta, several writers—Carini, Paranhos, Splendore, Escomel, and others—have described a very grave form of leishmaniasis occurring in certain South

Fig. 59.—Ulceration of hard palate and nares in espundia. (After Splendore.)

American countries *—Brazil, Bolivia, Peru, Paraguay. In Paraguay it has assumed epidemic characters, and a large proportion of the population in certain districts is said to be affected.

The disease begins as a sore on some mucous surface (Fig. 59). The sore is of the chancrous form of the ordinary oriental-sore type. It heals in time,

* La Cava has reported a similar disease affecting the nose and mucous membrane of the mouth, in Italy, in localities where oriental sore is also found.

leaving a characteristic scar. After an interval of months or years, fungating and eroding ulcers (Fig. 60) of a most intractable character break out on the tongue, and on the buccal and nasal cavities, destroying and obstructing them, and ultimately, after years of suffering, leading to the death of the patient by

Fig. 60.—Ulceration of nares and lips in espundia. (*After Splendore.*)

exhaustion. The lymphatic glands are often involved, but the abdominal and thoracic organs are spared.

Leishman bodies are to be found, though not in great profusion, in scrapings and sections of the fungating ulcers; giant cells also occur. Dermal ulcers of oriental-sore type may concur with the buccal and nasal lesions. It is believed that the original sore in this grave form of leishmaniasis develops at the site of the bite of a jungle insect of unknown species.

CHAPTER XII

RELAPSING FEVER

Synonyms.—Febris recurrens; spirillum fever; famine fever; tick fever.

Definition.—An acute infectious disease, or, possibly, a group of infectious diseases, characterized by fever of sudden onset and, after several days (one to seven), rapid subsidence, and which may relapse at intervals of from one to seven or more days for an indefinite number of times. It is caused by spirochætes which are present in the blood during the fever and are transmitted by certain insects (bug, body louse) or by certain ticks (*Argas*, *Ornithodoros*).

Geographical distribution.—Relapsing fever is found in Europe, Asia, Africa, America, and probably in Australasia. In Europe it occurs in Britain and, especially, in Ireland; also in Norway, Denmark, Germany, Russia, and Turkey. In Russia there have been many epidemics; it attacked the Grand Army in the retreat from Moscow, the allied armies in the Crimea, and, also, the armies of both sides in the Russo-Turkish War. In Africa the disease has long been known in Egypt, the Soudan, and Algeria. Recently, Philip Ross, Milne, and Cook found it in Uganda, Dutton and Todd in the Congo Free State, Wellman in Angola, and Koch in German East Africa. In Asia relapsing fever is known to occur in China, in Sumatra, and in India where Carter's classical investigations were made. In America it was recognized in the United States in 1844; in 1869 it was epidemic in New York and Philadelphia. It is probably widely distributed throughout South and Central America.

From the symptoms, as far as they are known, and from the fact that they are communicated by tick bite, we are justified in conjecturing that th

carapata disease described by Livingstone and Kirk as endemic in the Zambesi basin, the miana disease of Persia, and a similar disease described by Alleman in Mexico may be spirochæte-produced diseases, and forms of relapsing fever.

History.—Relapsing fever was known to Hippocrates. He describes an epidemic which he witnessed on the island of Thasos. Among other cases, he quotes those of two brothers, in one of whom the initial paroxysm lasted seven days, in the other six; the intermission in one was five days, in the other six; the relapse in both lasted five days. He further mentions the splenic enlargement, the jaundice, the liability to abortion in pregnant women, and the tendency to menorrhagia. From the time of Hippocrates onwards there is no further notice of relapsing fever in medical literature until 1770; in that year Rutty in his book on the diseases of Dublin described it.

In 1873 Obermeier discovered the spirochæte. In 1897 Tictin stated that the parasite and the disease were communicated by the common bed bug; he infected a monkey with relapsing fever by subcutaneous injection of blood obtained from the stomach of a bug which had previously fed on another monkey inoculated with the disease.

In 1904 Philip Ross and Milne in Uganda, and rather later, but independently, Dutton and Todd on the Congo, discovered that in Africa the spirochæte was communicated by the bite of a tick, *Ornithodoros moubata*. The last two observers found that the parasite could pass into the egg and larva, and so confer infective powers on the mature tick of the succeeding generation. In 1907 Mackie recorded an outbreak of relapsing fever in which lice apparently served as the transmitting agent—a view favoured by the experiments of Nicolle and others, who further state that the infection can be transmitted hereditarily to the offspring of infected lice.

Etiology.—Experiments and observation have proved that the various forms of relapsing fever are caused by *Spirochæta recurrentis* or an allied organism.

Spirochæta recurrentis (*S. obermeieri*) is a delicate spiral filament (7 to 9 μ by 0·25 μ) provided, as shown by appropriate staining (Loeffler's whip stain), with a long flagellum (5 to 7 μ by 0·1 to 0·2 μ). The body of the parasite may have three, four, or six bends or turns, the flagellum from three to five. By the Romanowsky method the body of the parasite usually stains uniformly, with the exception of the extremities, which are pointed and take only a very faint tint. In fresh blood the spirochætes, propelled by the flagellum, exhibit very active screw-like movement. Some are longer than others, the long forms resulting from end-to-end attachment of two or more parasites. That this is the explanation of the long forms, which may measure from 16 to 100 μ, is shown by staining. In those measuring from 16 to 19 μ we find a flagellum at each end of the filament and a pale zone in the middle, the pale zone corresponding to the approximated lightly staining extremities above referred to. The still longer forms admit of a similar explanation Although the normal habitat of the spirochætes is the liquor sanguinis, occasionally they are seen in the red blood-corpuscles.

Obermeier and von Jaksch describe certain refractile bodies present in the blood during the fever intermissions. The latter author says that he has observed the development of these bodies into short rods from which the typical spirochætes are eventually evolved. This observation has not been confirmed.

Demonstration of the parasite.—It is necessary to remember that the parasite only occurs in the blood during the febrile stage of the disease, disappearing from it completely during the non-febrile intervals. In some forms and cases of the disease it is present in large numbers in every field of the microscope; in other forms and cases it is so scanty that many fields have to be examined before a single specimen can be discovered. In thin films of fresh blood its presence can usually be recognized from the agitation its movements communicate to the adjacent corpuscles. In dried and fixed films the stains in general use for malaria work suffice for its demonstration. The

indian-ink or Burri method is invaluable for showing up the spirochæte. The technique is as follows:—One drop of suspected blood and one drop of indian ink (Pelican brand) are taken up in a platinum loop and mixed together on a slide. The spirochætes appear as white wavy lines on a dark background.

Harrison suggests a modification of this method, substituting a mixture of collargol powder 1 part, distilled water 19 parts, for the indian ink. The mixture is well shaken up in a black bottle before use. The dark-ground method of illumination is admirably adapted for demonstrating these parasites in a living state. A very strong illuminant—preferably a high-power electric light (Nernst lamp), not always procurable in the tropics—is required.

The "infective granule" of Balfour.—Balfour has called attention to an interesting phenomenon occurring in the spirochæte infection of fowls, the exact signification of which has not been determined, but which may have reference to the relapses that are so striking a feature in spirochæte infection. In spirochæte-infected fowls certain minute highly refractile granules are to be seen in a proportion of the red blood-corpuscles. At one time Balfour considered that these granules resulted from the breaking down of the spirochætes which are frequently observed to enter, move about in, and coil up in the red cells. But by employing the dark-ground method of illumination he was led to conclude that these granules enter the corpuscles as granules, and that they are derived from spirochætes free in the liquor sanguinis. He describes the process of "granule shedding" as follows:—

"By the use of the dark-field method, and more especially by practising liver puncture on chicks at the crisis or on chicks which have been given a sufficiently large dose of salvarsan, I have found that in the liver in particular, also in the spleen and lung, the spirochætes undergo an astonishing change. They discharge from their periplastic sheaths spherical granules, and it is apparently these granules which enter the red cells, develop in them, and complete a cycle of schizogony. The appearance is very remarkable. If a well-infected chick be given a dose of salvarsan, the peripheral blood is soon cleared, or nearly cleared, of spirochætes. If then a drop of

liver juice be examined by the dark-field method, it will be found swarming with spirochætes and with highly refractile granules. The source of the latter is soon apparent, for attention will be directed to spirochætes which are not moving in the usual way, but are in a state of violent contortion, or are, so to speak, shaking themselves to and fro. Indeed, I cannot give a more apt comparison than by likening their movements to those of dogs which have been in water and are shaking themselves vigorously to dry their coats. The object of the spirochætes, however, is to rid themselves of the bright, spherical granules which can be seen within them, and which may or may not be aggregations of the so-called chromatin core. These are forced along the periplastic sheath and suddenly discharged, so that they become free in the medium and dance hither and thither as tiny solid, spherical, brilliantly white particles. In process of time the spirochæte loses its activity, becomes difficult to see, and eventually all that is left of it is the limp and lifeless sheaf drifting aimlessly in the fluid and liable to be caught up and swept away by some still vigorous parasite. Such a sheath may still retain one or two of the granules which it has been unable to discharge."

Nature of the spirochæte.—Opinions differ as to the biology of the spirochæte—whether it belongs to the bacteria or to the protozoa. Novy and Knapp,* who regard it as a bacterium, point as evidence to (*a*) the pale zones in the stained long forms as possibly indicating transverse division; (*b*) the spiral arrangement and very delicate nature of the flagellum, so unlike in these respects that of the flagellata; (*c*) its not being killed rapidly and disintegrated by the slow addition of water to the blood; (*d*) its not being provided with an undulating membrane or being attracted, as the trypanosomes are, by air bubbles in microscopic preparations, the trypanosomes in such circumstances arranging themselves around the bubble, their flagella pointing inwards; (*e*) its uniform staining; (*f*) absence of nucleus and blepharoplast. In favour of the protozoal nature of the spirochætes are—(*a*) the presence of an undulating membrane but no flagella in certain species, as for example *S. plicatilis* and *S. refringens*; (*b*) the elements constituting a long spiral are all of approximately the same length, which is that of the individual spirochæte; (*c*) the parasites are not all of the same thickness, some being twice the diameter of others,

* *Journal of Infectious Diseases*, 1906.

facts suggesting a longitudinal, that is protozoal, rather than a transverse or bacterial method of division; (*d*) the parasite keeps alive for many days—forty—in the body of the bug; (*e*) at least in the case of the African form, it enters the egg of the tick in utero; (*f*) it is communicated by an arthropod.

Schaudinn propounded the view that the leucocytozoon of the owl (*L. ziemanni*), after fertilization in the gut of the mosquito, gave rise to an enormous number of trypanosome-like forms which he regarded as spirochætes. These he considered were a flagellated stage of an intracellular organism and, therefore, belonged to the protozoa. He stated that he had compared his mosquito-bred flagellates with *S. recurrentis* and *S. anserinum*, and that he found they agreed completely in morphological character with what he considered the spirochæta stage of *L. ziemanni*. Before his death Schaudinn seems to have modified his opinion, for in a later paper he states that *L. ziemanni* is far removed from the typical spirochætes such as *S. recurrentis*.

Novy and Knapp claim that their observations on the cultivation of trypanosomes in the blood of birds which, so far as microscopical examination went, appeared to be free from these organisms, show that Schaudinn, probably unconsciously, worked with mixed infections; and that the trypanosomes which he regarded as a stage in the life of the intracellular *L. ziemanni* were not in any way related to the spirochætes, but merely a trypanosome derived either from birds or from trypanosomes of the mosquito, which is itself very liable to this type of infection.

This question of the place in the natural kingdom of the spirochætes of relapsing fever is still (1914) undecided. The trend of some recent investigations is to relegate them to the bacteria. Lately, Dobell,* as the outcome of improved technique, holds that the argument founded on longitudinal division for regarding them as protozoa is based on imperfect observation; and that the argument based on hereditary transmission through the tick is equally inap-

* *Arch. für Protistenkunde*, 1912.

plicable, seeing that we now know that a bacterium, *B. cuenoti*, is hereditarily transmitted by passing into the germ cell of the cockroach. Moreover, Noguchi has succeeded in cultivating two strains of pathogenic spirochætes—*S. duttoni* and *S. obermeieri*.

Cultivation.—The successful cultivation of this as of other spirochætes has been performed by Noguchi, and more recently with simplified technique by Hata. For information as to the method, *see* p. 642. According to Noguchi the organisms multiply by longitudinal division in artificial culture.

Different species, or strains, of relapsing-fever parasites.—Having had the opportunity of examining the blood of a patient from Gibraltar suffering from her eighth paroxysm of relapsing fever, I suggested, on the

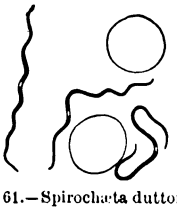


Fig. 61.—Spirochæta duttoni.

ground of the unusually large number of relapses and the locality in which the infection was acquired, that there might be several forms of this type of disease, due to different species or varieties of spirochætes. In 1905, in the discussion following the reading of Dutton and Todd's paper on tick fever (Brit. Med. Assn., 1905), Sambon made a similar suggestion, basing it on the wide geographical distribution of relapsing fever, the apparent clinical differences of the disease in different places, and the diversity of animals believed to transmit the infection. Koch pointed out that in African tick fever the febrile stages are shorter (under three days) than in European relapsing fever, and that the spirochætes in the blood are comparatively scanty; similar observations have been made by Philip Ross and Dutton and Todd. Novy and Knapp, in comparing specimens of spirochætes from European and African cases, noted that the spirochætes of the

African disease are twice as long (16 μ) as the classical *S. recurrentis*, and, moreover, that the former has a tendency to dispose itself in figure-of-eight coils or in perfect circles. The Indian species they also incline to regard as distinct. The latter, like *S. recurrentis*, measures about 8 μ, but is apparently thinner and more flexible, forming less regular spirals, which, moreover, vary in width. Like the spirochætes of African tick fever, the Indian variety has a tendency to form loops.

For the African form Novy and Knapp propose the name *S. duttoni* (Fig. 61); *S. carteri* would be an appropriate name for the Indian form. An Egyptian and an American spirochæte, named respectively *S. berbera* and *S. novyi*, have also been described. Such a nomenclature and differentiation can be regarded only as provisional: the evidence as yet is far too limited to warrant its permanent adoption; the recent elaborate experiments of Todd and Breinl have shown that the immunity conferred through infection with the spirochætes of Indian relapsing fever does not protect against the African form, and vice versa, thereby proving that, at least pathologically, they are distinct.

Mode of transmission.—I have already referred to the Persian disease called miana fever, and to the carapata disease of the Zambesi valley, as forms of relapsing fever. They are certainly communicated by ticks, *Argas persicus*, or more probably, according to Balfour, by *Ornithodoros savignyi* in one case, *Ornithodoros moubata* in the other. Marchoux and Salimbeni were the first to show that a similar disease of fowls caused by the *S. gallinarum* is transmitted by a tick, the *A. miniatus*, which Neumann pronounces to be identical with, or a mere variety of, *A. persicus*. The relapsing fever of Europe has been supposed to be conveyed by the common bed bug, *Acanthia lectularia*; that of India by lice, possibly by mosquitoes, fleas, and bugs; that of Africa by ticks. Proof of transmission by the bug is by no means complete. Breinl, Kinghorn, and Todd, notwithstanding repeated attempts, failed to communi-

cate the disease by means of these insects. But as we have now reason to believe that there are several strains of pathogenic spirochætes producing disease in man, it may be that these observers have not worked either with the appropriate kind of spirochæte, or with the appropriate species of *Acanthia*. Thus may we explain the positive results claimed by Sikiel, in Odessa, and by other Russian experimenters. There can be no doubt from the experiments of Philip Ross and Milne in Uganda, of Dutton and Todd on the Congo, and of many others, that the African species, *S. duttoni*, is normally conveyed by the tick *Ornithodoros moubata*, and that it can be transmitted not only by the animal that has bitten the infected individual, but by its progeny. The spirochæte has been demonstrated in the egg of the tick by Koch, and Leishman describes certain groups of "coccoid bodies," which may have been derived from spirochætes, in the same situation. It may be in this way that the hereditary transmission of the spirochæte in ticks and lice is effected. According to Leishman the spirochætes are commonly found in ticks' eggs laid in the tropics, but not in this country; but Balfour believes that these eggs contain his infective granule (*see* p. 226). Symptoms of a successful infection by the tick appear in from five to seven days.

It would seem that the various insect transmitters act merely in a more or less mechanical way and that there is no essential biological relationship between the parasite and the transmitter, as is the case with the malaria parasite and the mosquito, or with the trypanosome and the tse-tse fly. The spirochæte is abstracted with the blood when the insect transmitter feeds; it multiplies by breaking up into refractile granules* in the gut and Malpighian tubes of the latter as in a culture-tube, and is afterwards passed out with the fæces and deposited on the skin of any human or other warm-blooded victim on which the

* Recently doubt has been cast on the validity of Leishman's and Balfour's work on this subject by Marchoux and Couvy, who conclude that the granules in the tick bear no relation to the spirochætes.

infected insect may subsequently feed. The irritation caused by the bite of the insect provokes scratching and consequent inoculation of the deposited spirochætes.* The parasite is not introduced by the mouth parts of the insect.

In the case of *O. moubata* the hereditarily infected nymph can communicate the disease (Nuttall). The tick itself has been shown to be infective up to a year and a half after the initial feed on spirochæte-containing blood.

It is undoubtedly the case that in one part of the world the spirochæte of man is transmitted by one species of blood-sucker, and in another part of the world by another species of blood-sucker; that the various relapsing fever spirochætes exhibit slight morphological differences; that their serum reactions differ; and that the fevers they cause are in some respects different clinically. It is not justifiable, however, to conclude on these grounds alone that the various strains of pathogenic spirochætes are specifically distinct. It has been ascertained that as regards some of the strains their usual transmitters are interchangeable. It may well be that the continued passage of a given strain through many generations of the same species of insect transmitter may confer on the spirochæte concerned special morphologic and pathogenic qualities, without at the same time transmuting it specifically. Indeed, it would seem that opportunity as supplied by the presence of an efficient insect transmitter, the habits and circumstances of the inhabitants, and the introduction of a pathogenic spirochæte are the principal circumstances that determine the endemicity or epidemic prevalence of relapsing fever; and that the insect transmitter has much to do with the pathogenic qualities of the organism that has been cultivated in its alimentary canal for countless generations.

Animal experiments.—It was generally stated

* In the act of feeding, the tick occasionally voids excrement and exudes a few drops secreted by the coxal glands situated in the first intercoxal space. The coxal fluid dilutes the fæces, thereby facilitating access to the wound inflicted by the bite of the tick or by scratching.

that *S. recurrentis* (*S. obermeieri*) could be transferred only to man and monkey. Novy and Knapp infected white mice and white rats. The former they found were especially susceptible, the organism appearing in the blood within twenty-four hours of inoculation and persisting to the third day (eighty hours). About this time they disappear for several days from the blood of the infected mice and until the commencement of relapse. The first relapse may be followed by a second, third, or even a fourth, the number varying in individual mice; with each relapse the parasites reappear in the blood. The interval between the relapses, counting from the first appearance of spirochætes in one to their first appearance in the next relapse, is generally about seven days; occasionally it is only two; sometimes it is as long as ten days. The number of spirochætes in the relapses is much smaller than in the first paroxysm, clearly indicating the development of a partial immunity. Recovery in mice, as in other animals, is the rule.

The same observers found rats to be susceptible, but in them the progress of the disease was different. The period of incubation was longer (forty hours), and there were no relapses. As a result of the consecutive passage of the spirochætes through a long series of rats its virulence was augmented, so that the incubation period became reduced to fifteen or eighteen hours, and the persistence of the parasite in the blood prolonged to sixty hours instead of, as originally, forty-eight hours; at the same time the spirochætes became far more abundant.

The parasite, which is present not only in the circulating blood but in all the organs, seems to produce no serious pathological change in the rat beyond great temporary enlargement of the spleen. Recovery is practically invariable. Young rats are more susceptible than old rats. Immunity persists for many months.

Rabbits and guineapigs are refractory.

Immunity.—Sabritschewsky in 1896 showed that when equal parts of spirochæte-infected

serum, and normal serum are mixed, the spirochætes survive longer than when the infected blood is mixed with that of an individual who has recovered from relapsing fever. He accordingly concluded that the cause of the crisis in relapsing fever and of subsequent immunity was the development of a germicidal substance in the blood. He was the first to apply serum-therapy in the treatment of relapsing fever. He obtained an anti-spirochæte serum by repeated inoculation of the horse with human spirochæte-containing blood. The value of this serum was successfully established by Löwenthal; of 87 patients treated, 43 (49 per cent.) recovered without a relapse.

Novy and Knapp have proved the presence of a powerful germicidal substance in relapsing fever blood by comparing the viability of the spirochætes in blood taken (1) at the onset of the disease, (2) during crisis, (3) twelve to twenty-four hours after disappearance of parasites, and (4) from animals hyperimmunized by repeated infection. In the case of the first, the spirochætes live and are mobile for forty days, and the blood will continue infective up to thirty-seven days; in the case of the second, no living spirochætes are to be found after twenty-four to forty-eight hours; in the third, the parasites die in from thirty to sixty minutes; in the last, they are killed instantaneously.

They further showed, by examining the blood during the decline of the fever in an infected animal treated with immune blood, that the presence of agglutinating and germicidal bodies could be demonstrated *in vivo* from hour to hour. The parasites are seen to form agglutination rosettes and long agglutination filaments of 70 to 100 μ.

Treated *in vitro* with hyperimmune serum the spirochætes rapidly become unrecognizable aggregations of granules.

Incubation period.—The incubation period usually lasts from two to ten days. In some instances the attack develops promptly on exposure; it is never delayed beyond the fourteenth day. In the

artificially inoculated, symptoms show themselves in from two to six days.

Symptoms. *European and Indian type.*—The onset is generally abrupt, being marked by chilliness or rigor, giddiness, vomiting, and intense headache. In the young there may be convulsions. Temperature rises rapidly to 104° or 105° F., sometimes even to 108°. The pulse is rapid, 110 to 130. Should fever run high there may be delirium. The skin is dry, although, especially during the first day, occasional sweats may break out. A slight icteric tinting of the conjunctiva is usual; not infrequently jaundice is marked. The spleen is invariably enlarged and tender. The tongue is coated and moist except in bad cases, in which it may become dry and brown. The bowels, as a rule, are confined. Occasionally herpes labialis is noted, and in certain epidemics a rash of rose-coloured spots on the trunk and limbs has been observed. Some authors describe petechiæ. A slight bronchitis is not uncommon. The urine, not appreciably diminished in amount, is very high-coloured. This, the primary fever, lasts for from five to seven days. At first the morning is usually lower than the evening temperature, but on or about the third day the evening temperature rarely rises above that of the morning. On the fourth, fifth, or sixth day there is again a rise of temperature, sometimes with delirium, ending in crisis of profuse sweating and diarrhœa. The temperature now falls rapidly to normal or subnormal, sometimes dropping in the course of a few hours as much as 10° F.; in the latter event, especially in elderly or delicate patients, there may be dangerous collapse.

The initial pyrexia, called *first paroxysm*, is followed by a *first period of apyrexia* during which the patient recovers so rapidly that after four or five days it may be difficult to keep him in hospital. But from seven to nine days after the crisis, that is about the fourteenth from the commencement of the attack, rigor again occurs, followed by a second attack of fever—*first relapse*. This may be more severe than the initial paroxysm; usually it is milder and seldom

so long. During its continuance the secretion of urine is considerably increased; sweating also is profuse and prostration marked.

With the defervescence of the first relapse the patient enters on the *second period of apyrexia*, which is usually coincident with convalescence. But in some patients a *second relapse* may occur, usually about the twenty-first day counting from the commencement of symptoms. This second relapse rarely lasts longer than three days, and is generally milder than the previous paroxysms. In rare instances three, four, five, or even more relapses have been observed. Convalescence may be protracted, and complicated with such sequelæ as nephritis, ophthalmia, otorrhœa, pneumonia, neuritis, parotitis, adenitis. In pregnant women abortion is the rule.

African type.—The African tick-conveyed spirillum fever, although as regards the type of fever resembling the classical European and Indian forms, differs from these in some important particulars. The initial fever is not usually so prolonged, generally terminating in crisis within three days. Diarrhœa and dysenteric symptoms are not uncommon. The apyretic intervals are of very irregular duration, being, according to Philip Ross, sometimes as short as one day, sometimes as long as three weeks; and instead of only one or two relapses, as in ordinary relapsing fever, there may be as many as eleven, five or six relapses being the rule. The fever, though shorter, is as severe in the relapses as in the initial paroxysm, but the intervals tend to become longer. In some instances the reverse is the case, perhaps in both particulars. Sometimes the fever may assume a low chronic form, it may be with severe headache and vomiting. Iritis is not an uncommon complication or sequela. As already stated, the parasites are usually very scanty in peripheral blood and may be hard to find.

In the natives of the endemic districts the disease, as generally observed, is not nearly so severe as in Europeans and strangers, being usually limited to a paroxysm or two of one or two days' duration.

SYNOPTICAL TABLE OF VARIOUS STRAINS OF SPIROCHÆTE AND CLINICAL SYMPTOMS OF THE RELAPSING FEVERS THEY EVOKE IN MAN

(Compiled mainly from Mackie, Chosky and Balfour)

	EGYPT *Spirochæta berbera*	ALGIERS *Spirochæta berbera* (?)	EUROPE *Spirochæta recurrentis (obermeieri)*	AFRICA *Spirochæta duttoni*	AMERICA *Spirochæta novyi*	INDIA *Spirochæta carteri*
Minimal length	13·5 μ.	12 μ.	12 μ.	13 μ.	7–9 μ.	12 μ.
Shape . . .	Irregular open flexures.	Irregular open flexures.	Spiral.	Open flexures.	Regularly spiral.	Open flexures.
Flagella . . .	?	?	Peritrichous.	Peritrichous.	Terminal. (*Novy.*)	?
Animals susceptible.	Gerbils, slightly. Monkey (*Cercopithecus*).	Rats and mice, with difficulty. Monkeys (*Macacus*).	Small rodents, only after passage through monkeys.	Small rodents and many animals susceptible.	Small rodents very susceptible.	Small rodents infected with difficulty.
Course in animals.	Very mild.	As a rule mild.	Mild.	Very severe.	Severe.	Very mild.
Subinoculations in animals.	Gerbil to gerbil, positive.	Rat to rat, or mouse to mouse, with difficulty. Monkey to monkey.	Monkey to monkey, mouse to mouse, positive. (*Fülleborn and Meyer.*)	Monkey to monkey, positive. Same for most animals. (*Breinl, Kinghorn & Garrett.*)	Monkey to monkey, and mouse to mouse, positive.	Monkey to monkey, and mouse to mouse, positive. (*Mackie.*)
Course in man	Fairly severe. First attack 2–8 days; two or three relapses.	Fairly severe. First attack 2–8 days; two or three relapses.	One, sometimes two relapses. [days. Incubation period 5–7 Duration of attack 5–6 Apyrexia . . . 7–10	Severe—four or five relapses. [days. Incubation period 7–10 Duration of 1st attack 3 Apyrexia 1–8	Mild, rarely more than one relapse. [days. Incubation period 5–7 Duration, 1st attack 5–6 Apyrexia . . . 7–10	Severe, one or two relapses. [days. Incubation period . 7 Duration, 1st attack 5–7 Apyrexia . . 5–13
Parasites in human blood.	Variable.	Variable.	Heavy infection.			
Natural trans- [illegible]	Lice.	Lice. Ticks (*Argas persicus*). (*Sergent.*)	Lice. (?) Bed bug (*Acanthia lectularia*).	Ticks (*Ornithodoros moubata*).	Lice (?) Ticks (*Ornithodoros talaje*) (?).	Lice. (?) Bug (*Cimex rotundatus*).
[illegible] *ons*	?	Immune serum possibly without effect on *S. recurrentis* (*obermeieri*).	Immune serum without any effect on *S. novyi* or *duttoni*.	Immune serum without any effect on *S. novyi* or *recurrentis* (*obermeieri*).	Immune serum without any effect on *S. recurrentis* (*obermeieri*), *duttoni*, or *carteri*.	Immune serum without any effect on *S. novyi*.

The mildness of these attacks is probably explained by a partial immunity which has been conferred by previous attacks.

For a summary of the symptoms evoked by the various strains of relapsing-fever spirochæte, *see* the Table on p. 237.

Mortality.—The death-rate is usually below 6 per cent. In the feeble and old, death may take place at the height of the first paroxysm.

Diagnosis.—This disease is readily confounded with malaria, enteric, typhus, and influenza. The detection of the spirochætes with the microscope, or by animal injection, is the most reliable method of diagnosis. At an early stage the relapsing character of the clinical phenomena, not having declared itself, is not available as an aid to diagnosis, but at a later period the history of a fever which had relapsed about fourteen days from the commencement of the disease should be regarded as highly suggestive of relapsing fever.

Morbid anatomy.—The spleen is usually large and soft. Liver, kidneys, and heart show cloudy swelling. The skin in fatal cases is usually jaundiced, and there may be submucous petechiæ. The bone-marrow is hyperæmic. There is generally a marked polymorphonuclear leucocytosis.

Treatment.—Ehrlich's discovery of the value of salvarsan in the treatment of syphilis naturally suggested that this drug would prove of use in the other spirochæte-caused diseases—yaws and relapsing fever. Fortunately the surmise has proved to be well founded. Intravenous injection of from 3 to 6 gr. of *salvarsan* in relapsing fever, after a short aggravation of symptoms is promptly followed by disappearance of the spirochætes from the blood and, in the vast majority of cases, recovery. Should relapse occur—a rare event—a second injection may be given.

Atoxyl, so potent against trypanosomiasis, is useless in relapsing fever.

Methods of administering salvarsan.—Salvarsan (dioxydiamido-arseno-benzol, "606") is sold as a yellow powder hermetically sealed in glass phials. It may be given intra-

venously, intramuscularly, subcutaneously, or by the mouth in alkaline solution.

Of these, the intravenous and intramuscular methods are the ones to be recommended; the subcutaneous, and occasionally the intramuscular, injections are apt to be followed by such extensive sloughing as to require surgical interference.

The intramuscular injection—a suspension of the drug in oil—is generally made into the buttocks: the dose is 7–8 gr. (0·4–0·5 grm.) in the male; 4½ gr. (0·3 grm.) in the female; and ½-gr. (0·03–0·04 grm.) for each year of age in children is taken as the standard.

For intravenous injection the glass phial containing 9 gr. (0·6 grm.) is taken, the contents carefully added to 50 c.c. physiological saline solution (made with freshly distilled water), and dissolved thoroughly by adding 18–23 drops of 15 per cent. soda till a precipitate forms which redissolves on addition of more soda. The solution should be made up to 300 c.c. In a man the whole amount may be injected; in a woman, 200 c.c. or less.

The vein should be exposed and the needle, attached to a funnel and a glass-jointed rubber tubing, inserted. Care should be taken that the funnel and tubing are filled with saline beforehand and all air excluded, the flow being controlled by a clip or a stopcock. A special apparatus has been devised and placed on the market by Martindale.

It is advisable to run into the vein 100–200 c.c. of normal saline first, and then to add the salvarsan solution warmed to the temperature of the body.

Neo-salvarsan is an oxidized product of salvarsan, possessing the advantage of being less toxic and more soluble; consequently it may be given in larger doses, 15 gr. being tolerated by an adult man. It is, therefore, preferable to the older product. It is easily soluble in normal saline, forming a neutral solution.

According to Levaditi the most favourable time for the administration of salvarsan is during the "precritical" period of the spirochætal infection, when it causes a precocious crisis, thus enabling the organism to combat the infection by the usual processes—spirochæticidal bodies and phagocytosis.

Serum-therapy.—Novy and Knapp have proved that active immunity follows recovery from spirochæte infection, and that this immunity can be increased to a remarkable degree by successive injections of spirochæte-infected blood. They have further shown that passive immunity can be imparted by the injection of recovered or of hyperimmunized blood, and that both active and passive immunity persist for months. Preventive inoculations have been successfully practised in rats, mice, and monkeys. Infected

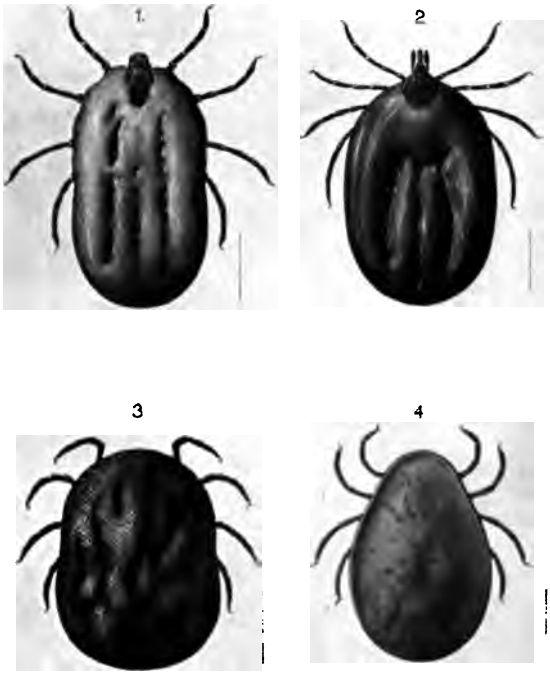
animals can be promptly cured by the injection of hyperimmunized serum, and relapses can be prevented by the same means. Although Todd has not been so successful in similar experiments, it seems probable that we have in these observations a basis for the prevention and cure of relapsing fever in man.

Prevention.—The fact that the spirochæte is conveyed to man by bug, or louse, or tick bite indicates that personal and domestic cleanliness and the avoidance of people and places infested with such vermin must form the basis of successful prophylaxis. Especially to be avoided in Africa are the resting-places of caravans and travellers, and the huts of natives. The mosquito net, a bed well off the ground, and a night-light are indispensable in that country, where the nocturnal habits of *Ornithodoros moubata* render the hours of sleep especially dangerous.

TICKS

Recent developments in human and veterinary pathology have shown that ticks play an important part in the transmission of disease. They are widely distributed, almost every animal either having species special to itself or being liable to attack by species of a wider zoological range. They belong to the order of the *Acarina*, of which they are by far the largest specimens. They are always visible to the naked eye, and the females are almost invariably larger than the males. In some species the ovigerous females, when gorged with blood, may reach a length of nearly half an inch. As a rule they are temporary parasites, but some live in a quasi-permanent manner on the body of their host; and occasionally a few, as the sheep tick, *Ixodes reduvius* (Plate VI., 2), may even burrow beneath the skin. They differ from insects in possessing four pairs of legs, and in having the three regions of the body—head, thorax, and abdomen—fused into one unarticulated mass. This latter feature also distinguishes them from the spiders, in which the abdomen is clearly distinct from the cephalothorax.

After impregnation the female tick attaches herself to her host. Becoming enormously distended with its blood, she drops off and secretes herself in some convenient hiding-place where she deposits her eggs, which are small, yellowish, roe-like grains, amounting in some cases to thousands. Oviposition begins from two to ten days after the host has been quitted, and goes on for several days. In due course (two or three weeks under favourable conditions) the eggs are hatched. The larvæ look like minute moving grains of sand. They are characterized by having only three pairs of legs, no stigmata, and no



TERZI

Ticks (females).

1, Margaropus (Boophilus) annulatus (partially distended); 2, Ixodes reduvius (partially distended); 3, Ornithodoros moubata; 4, Argas persicus.

PLATE VI.

sexual orifice. A suitable opportunity presenting, the larva attaches itself to its vertebrate host. After a period of growth it goes through a first moult (ecdysis), and emerges from its larval skin as a *nympha*, provided with eight legs instead of six, and with a pair of large stigmata placed, one on each side of the body, behind the fourth pair of legs. After a second period of growth it becomes sexually mature. The nymphs undergo three moults, the third bringing them to the imaginal condition. In some species, as in the case of *Margaropus boris*, the metamorphosis from larva to nymph, and from nymph to imago, takes place upon the same host, the parasite remaining attached during the process. In other species, as in the case of *Hæmaphysalis leachi*, the tick, before each moult, drops off as soon as it ceases feeding, and in consequence has to find a host three times during its life instead of once. Having reached maturity the sexes unite. After fertilization the male dies, but the female proceeds to engorge herself with blood for the development of her ova.

On account of the difficulty of finding an appropriate host, ticks at all stages are endowed with a phenomenal capacity for fasting. Megnin found *Argas persicus* alive after a fast of four years' duration.

Ticks are referable to two families, the *Ixodidæ* and *Argasidæ*, differing both in structure and in life habits. Their characteristics and generic classification are indicated sufficiently for practical purposes in the synoptical Table on p. 243.

The species which are of particular interest to the human pathologist are *Ornithodoros moubata*, *O. savignyi*, and *Argas persicus*; the first being the transmitter of the spirochæte of African relapsing fever, the third of the spirochæte of the miana disease (Balfour). It is quite likely that other species will in the future be found to be concerned in the transmission of disease germs to man. Important animal diseases due to *Spirochætæ* and *Babesiæ* are also known to have tick transmitters. *Spirochæta gallinarum* of fowls in Brazil is transmitted by *Argas miniatus*. *Babesia bigemina* (*bovis*) is conveyed in various countries by different species of *Margaropus*, such as *M. annulatus* (Plate VI., 1), *M. australis*, *M. decoloratus*; *Theileria parva* by *Rhipicephalus appendiculatus* and *R. simus*; *Babesia ovis* by *R. bursa*; *Nuttallia equi* by *R. evertsi*, and *Babesia canis* by *Hæmaphysalis leachi* and *Dermacentor reticulatus*.

Ornithodoros moubata (Murray) (*O. savignyi* var. *cœca*, Neumann) is extensively distributed throughout tropical Africa (Plate VI., 3). Its body is flattened from above downwards, and is oval in outline. Its colour, when alive, is greenish brown. The integument is hard, leathery, covered with close-set shining granules or tubercles, and marked both above and below with symmetrically arranged grooves. The females may attain about 8 mm. in length by 6 to 7 mm. in breadth, and moult frequently. This species is widely distributed in Africa, from Uganda and Somaliland in

the east, and Congo and Angola in the west, to Namaqualand and the Transvaal in the south.

In habit *Ornithodoros moubata* resembles the common bed bug. It lives in the huts of the natives, hiding during the day in cracks in the walls and floors, or in the thatched roofs, and moving about actively during the night in search of nourishment. It attacks both man and beast. It feeds slowly, and would be unable to get much blood from any but a sleeping person. Dutton and Todd observed that a big female might remain, firmly fixed, feeding on a monkey for two or three hours before it finally dropped off, distended to the size of a cherry. *O. moubata* deposits its eggs in batches of fifty, seventy, or a hundred. Dissection has shown that only a few eggs mature at a time. The fertility of the female is favoured by liberal feeding. The females lay batches of eggs after each feed, but do not continue to moult. The eggs hatch in about twenty days. In the case of this tick, Dutton and Todd have observed that the larval stage is practically omitted. About seven days after oviposition the hexapod larva can be seen to be forming within the translucent egg-shell. About the thirteenth day the egg-shell splits, and about the same time the larval skin splits also, and the eight-legged nymph throws off simultaneously both the egg-shell and its larval skin. There are several nymphal stages; the exact number has not been clearly ascertained. The largest nymphs may equal adults in size, and show a punctiform mark where the sexual orifice is situated in the adult.

An interesting feature, and one perhaps having a bearing on the etiology of tick-transmitted diseases, pointing as it does to a channel by which the eggs may receive a germ ingested by the parent, concerns certain cells in the stomach wall. The tick, while feeding, from time to time expels per anum a whitish material. This excretion is derived partly from the Malpighian tubes, and partly from the cells alluded to. In the stomach wall, nourished by the imbibed blood, these cells elongate towards the cavity of the ventricle; the other end, smaller and becoming clavate, splits and emits the elaborated nutriment into the general body cavity, where it mixes with the blood of the tick. The cell then, becoming globular, drops into the lumen of the stomach, constituting part of the white excretion expelled per anum. One can readily understand how, by the former route, a parasite could reach the tissues of the tick, including the ovaries. Balfour has infected chickens with *S. gallinarum* by feeding them on eggs of infected *Argas miniatus* (*persicus*).

O. moubata is especially common along the routes of travel. The rest-houses are always the most infested. The ticks are frequently carried long distances in mats or bedding, or in porters' loads which have been piled for safety in the rest-huts at night.

The natives of some places, and also the Boers, protect themselves by plastering their huts, both floors and walls, with

GENERIC CLASSIFICATION OF TICKS

- *Rostrum* terminal. *Dorsal shield* present. *Ambulacra* present. *Sexual dimorphism* marked — *Family* IXODIDÆ
  - *Anal groove* surrounding anus in front. — *Prostriata* IXODINÆ
    - Inornate, without eyes and without festoons. Spiracles round or oval. Palps of variable form. Tarsi without spurs. *Sexual dimorphism* pronounced. In the ♂ the venter is covered by non-salient plates; one pregenital, one median, one anal, two adanal, and two epimeral plates. Parasitic chiefly on carnivora, rodents, marsupials (platypus and kangaroo), bats, and birds. — **1. Genus IXODES.**
  - *Anal groove* containing anus behind. — *Metastriata*
    - (*a*) *Brevirostrata.* Rostrum short.
      - Inornate, without eyes but with festoons. Usually with short conical palps, whose second articles project laterally. Small size and slightly chitinized. *Sexual dimorphism* slight. The ♂ shows no ventral plates or shields. — **2. Genus HÆMAPHYSALIS.**
      - Usually ornate, with eyes and festoons. Short, broad, or moderate palps, and basis capituli rectangular dorsally. Spiracles sub-oval or comma-shaped. — **3. Genus DERMACENTOR.**
      - Inornate, with eyes and festoons. Short palps, with basis capituli hexagonal dorsally with prominent lateral angles. The ♂ resembles *Rhipicephalus* dorsally, *Dermacentor* ventrally. Spiracles sub-triangular or comma-shaped. — **4. Genus RHIPICENTOR.**
      - Usually inornate, with eyes and festoons. Short palps, and basis capituli usually hexagonal dorsally. The ♂ possesses a pair of adanal shields and usually a pair of accessory adanal shields. Spiracles bluntly or elongate comma-shaped. — **5. Genus RHIPICEPHALUS.**
      - Inornate, with eyes but without festoons. Short palps, and capitulum intermediate between that of *Rhipicephalus* and *Boophilus*. Highly chitinized. The ♀ with very small scutum. The ♂ with a median plate prolonged into two spines projecting beyond and to either side of the anus. Anal groove obsolete. Spiracles rounded or short, oval in both sexes. — **6. Genus MARGAROPUS.**
      - Inornate, with eyes but without festoons. Very short compressed palps ridged dorsally and laterally. Basis capituli hexagonal dorsally. Slightly chitinized. Unfed adults of small size. The ♀ with small scutum. The ♂ with adanal and accessory adanal shields. Spiracles rounded or oval in both sexes. — **7. Genus BOOPHILUS.**
    - (*b*) *Longirostrata.* Rostrum long.
      - Ornamentation absent or present, at times confined to the legs; with eyes, with or without festoons. Long palps. Basis capituli subtriangular dorsally. The ♀ approaching *Amblyomma*. The ♂ with a pair of adanal shields, and with or without accessory adanal shields, and two posterior abdominal protrusions capped by chitinized points. Spiracles comma-shaped. — **8. Genus HYALOMMA.**
      - Generally ornate, with eyes and with festoons. Long palps, of which the second article is especially long. Basis capituli of variable form. The ♂ without adanal shields, but small ventral plaques are occasionally present close to the festoons. Spiracles sub-triangular or comma-shaped. — **9. Genus AMBLYOMMA.**
      - Subgenus *Aponomma*. Devoid of eyes, or in which the eyes are poorly developed. Body frequently very broad. Occur almost exclusively on reptiles.
- *Rostrum* concealed by overlapping cephalothorax. *Dorsal shield* absent. *Ambulacra* present. *Sexual dimorphism* slight. — *Family* ARGASIDÆ
  - *Body* usually flat with thin edges. *Ventral grooves* absent or very shallow. *Eyes* absent . . . — Genus ARGAS.
  - *Body* with thick edges. *Ventral grooves* present. *Eyes* sometimes present . . . . . — Genus ORNITHODOROS.

endemic. Until recently it was always to be found in Havana. Formerly the Brazils enjoyed an absolute immunity; but from 1849, when yellow fever was introduced for the first time into Bahia by a ship from New Orleans, it was practically endemic in the large cities until the institution of anti-stegomyia measures recently. At Rio de Janeiro, although in some years the cases were few, it was never entirely absent. It is still very common in Manaos. In such places as New Orleans, Charleston, Monte Video, and Buenos Ayres, although now and again epidemics of great severity break out, several years may pass without its appearing. Some of these epidemic visitations bring a heavy death-bill; thus, in New Orleans, in 1853, 7,970 people died of yellow fever; in 1867, 3,093. In Rio, in 1850, it claimed 4,160 victims; in 1852, 1,943; and in 1886, 1,397. In Havana the annual mortality from this cause used to range from 500 to 1,600 or over.

Epidemiology. *Influence of atmospheric temperature.*—The histories of these and other epidemics show that the virus of yellow fever can be transported from one place to another, and that for its development in epidemic form it requires an atmospheric temperature of over 75° F. It ceases to spread when the thermometer sinks below this point, and it stops abruptly as an epidemic when the freezing-point is reached. Dampness favours yellow fever; it is therefore most prone to occur and to spread during the rainy season.

Usually a sea-coast disease.—The favourite haunts of the disease are the sea-coast towns, the banks of rivers, and flat delta country. Rarely does it pass far inland, or ascend high ground. Still, there are many exceptions to this general rule; for yellow fever has been found far inland, and at a considerable elevation (São Paulo, Brazil, 2,500 feet; Newcastle, Jamaica, 3,000–4,000 feet; Cuzco, Peru, 9,000–10,000 feet). Villages are seldom affected; nor does the disease readily spread if introduced into rural localities. In spreading inland it follows the lines of communication—railways, canals, navigable rivers.

A ship disease.—Ship epidemics were common occurrences formerly. The ideal haunt of yellow fever is the low-lying, hot, squalid, insanitary district in the neighbourhood of the wharfs and docks of large seaport towns.

A place disease.—It is, in a sense, a place disease like malaria. That is to say, if the patient be removed to a hitherto unaffected spot, his attendants and neighbours will not contract the disease, unless the spot itself first become infected. The occurrence of this place infection will depend on whether the particular locality affords in sufficient numbers the appropriate intermediary—the stegomyia mosquito—for the transmission of the germ brought by the patient. If the locality supplies this condition, then, for the time being, the disease will spread and become epidemic; if the locality does not supply this condition, then the disease will not spread. It is safe, therefore, to visit a yellow fever patient if he is lodged outside the endemic or epidemic area; but it is never safe for the susceptible to visit the endemic area, whether they come into direct contact with the sick or not.

Immunity acquired by prolonged residence or by a previous attack.—A well-established fact about yellow fever is that the natives of, and those who have lived for a long time in, the endemic area are practically immune from the disease; or, if they are attacked, the disease is usually of a very mild type. It is also said that if the native quits the endemic area his immunity decreases in proportion to the length of time he remains away; so that, after long absence, on his return to the endemic area he may be attacked just as an ordinary visitor might be. Further, those who enter the endemic area for the first time are the most susceptible, the susceptibility decreasing with length of residence. It has been inferred from this, perhaps —but not certainly—correctly, that at such places as Rio and Havana the endemicity of the disease was kept up by the continual influx of foreign and, therefore, susceptible visitors.

Race as influencing susceptibility.—Formerly it was believed that the negro is little liable to yellow fever,

blood-corpuscles in yellow fever, which he has named *Paraplasma flavigenum*, and which he regards as the germ of the disease. So far, this claim has not been accepted by yellow-fever experts, and is not supported by convincing experimental evidence.

Nature of the yellow-fever germ indicated by epidemiology.—In earlier editions of this book I remarked, "The reasons for the peculiar geographical limitation of yellow fever are but partially understood. A principal reason, undoubtedly, is that yellow fever belongs to a somewhat restricted class of diseases which, though communicable, are not directly so through immediate conduction from sick to sound; diseases whose germs do not pass quickly from the sick to the healthy, like those of scarlatina and smallpox, but have first, apparently, to undergo extracorporeally developmental changes that enable them to attack and to live in the human body. Such diseases, seeing that their propagation demands an additional condition—the extracorporeal state or medium—must necessarily be more difficult to acquire, must spread more slowly, and be more limited geographically, than the ordinary infectious diseases." These remarks, suggested by the peculiar epidemiological features of yellow fever, have received remarkable confirmation from the brilliant work of Reed, Carroll, Agramonte, and Guiteras, and by many subsequent workers.

The germ occurs in the blood. — This Reed, Carroll, and Agramonte have incontestably demonstrated. They injected into six non-immunes blood from yellow-fever patients. In this way, in five instances, they conferred the disease within the recognized limits of the incubation period. In another experiment they induced yellow fever by injection of defibrinated blood. By other experiments they showed that the virulence of the blood was destroyed by a temperature of 55° C. Another point, already alluded to, is that these experiments, taken in conjunction with others to be presently described, showed that the germ is present in the blood, at all events in a transferable state, only during the first

three or four days of the disease. Yet another point these experimenters sought to establish, viz. that this phase of the yellow-fever germ is so minute that it can pass through a Berkefeld filter. Further, that blood from a yellow-fever infection produced by injection of filtered serum will, on being injected into another non-immune, again confer the disease; proving that the virus so conveyed was capable of multiplying—that is to say, that it is not a toxin or chemical body merely, but that it is a living germ. These latter inferences are deduced from what was practically only one experiment. Although the evidence, therefore, is somewhat meagre, yet, considering the high order of the other work accomplished in the same field by these American observers, we are almost justified in concluding with them that, like the germ of rinderpest, of horse-sickness, and of foot-and-mouth disease, at least one phase of the yellow-fever germ as it exists in the blood, though particulate, is ultramicroscopic.

The mosquito the intermediary and diffusing agent of the germ of yellow fever.—Having satisfied themselves by direct observations, and by a long series of carefully conducted culture experiments on the blood, that the germ of yellow fever was not of an ordinary bacterial nature, guided by the epidemiological considerations detailed above, and encouraged by the recent discoveries in the etiology of malaria, the American observers thought that possibly, as in malaria, the mosquito was an essential factor in the life cycle of the yellow-fever germ, as Finlay had conjectured many years before. After some preliminary experiments, which unfortunately proved fatal to Dr. Lazear, one of the original members of this courageous band of observers, carefully planned systematic attempts were made to convey yellow fever by means of the bite of the common West Indian mosquito, *Stegomyia calopus* (*S. fasciata*). Twelve non-immunes, who had had no opportunity of contracting the disease from other sources, were bitten by mosquitoes previously fed on yellow-fever patients. Of the men so bitten, ten (83·3 per cent.)

developed the disease within the normal incubation limits—three to five days. Subsequently Guiteras and others, on repeating this experiment, have obtained similar results.

The germ not transferable by recently infected mosquitoes.—As might have been partly expected from the blood inoculation experiments already described, it was found that it was only mosquitoes that had fed during the first three days of the fever that were infective. It was further demonstrated that the germ must undergo in the mosquito some necessary developmental process, for it was not until twelve days had elapsed after feeding on yellow-fever blood that the experimental insects could convey infection. Repeated trials made with mosquitoes two to ten days after they had so fed invariably gave negative results; whereas the same insects rarely failed to infect when set to bite non-immunes at any time subsequent to the twelfth day after their yellow-fever blood meal. It was also proved that they retained their infective power for at least fifty-seven days.

These experiments fully explain—(1) The impunity with which a yellow-fever patient can be visited by a non-immune if outside the endemic area; the mosquitoes in the vicinity are not infective. (2) The danger of visiting the endemic area, especially at night; the mosquitoes there are infective and active. (3) The discrepancy between the incubation period, three to five days, of the disease, and the incubation period, fourteen days and over, of an epidemic; the necessary evolution of the germ in the mosquitoes infected by the original introducing patient demanding the space of time indicated by the difference between these two periods. (4) The clinging of yellow-fever infection to ships, buildings, and localities; the persistence of the germ in infected mosquitoes (*Stegomyia calopus*) which are known to be capable of surviving for five months and probably longer, after feeding on blood. (5) The high atmospheric temperature required for the epidemic extension of yellow fever; such temperature favours the

activities and propagation of the mosquito, and is probably also necessary for the evolution of the germ in the mosquito.

Since the announcement of these discoveries many independent observers and several commissions have studied yellow fever in its relation to the mosquito, but, beyond confirming the results of the original American observers and adding some facts in the bionomics of *S. fasciata*, there has been no great addition to our knowledge of the subject. The germ itself is still unrevealed.

Marchoux and Simond have given us several new facts about the yellow-fever germ. They have shown that, although it is arrested by the Chamberland bougie B, it can pass bougie F; that it will not infect if simply laid on a raw (blistered) surface; to secure infection it must be injected subcutaneously; that virulent blood-serum loses its virulence in forty-eight hours if exposed to the air at 24° to 30° C., but if protected by oil or vaseline will retain it for five days.

As regards *S. calopus*, the same observers note that to lay eggs she must first have a feed of blood, and that her eggs are deposited about three days after she has so fed. Before the first egg-laying, *S. calopus* is both diurnal and nocturnal in her feeding habits, biting at any time; subsequently she is strictly nocturnal in this respect. Therefore a stegomyia that bites during the day does not convey yellow fever. She is too young; any parasite she may harbour is immature. In this way is to be explained the impunity with which a yellow-fever centre may be visited during the day, although the visitor may be bitten by stegomyia. Europeans who live at Petropolis, a suburb of Rio de Janeiro, and are in the habit of visiting and transacting their business in the low-lying yellow-fever-haunted districts of the city, never contract the disease unless they are so imprudent as to pass the night in the latter. Marchoux and Simond further state that an infected stegomyia can communicate the yellow-fever germ to her eggs and so to the second generation of mosquitoes, and that

the latter become infective to man fourteen days after the hatching.

The parallelism between the etiology of yellow fever and that of malaria is very complete, and encourages the conjecture that the germ, like that of malaria, is of a protozoal nature; that as a result of a sexual process it undergoes growth and development in the mosquito; and that the sporozoites resulting from this process are emitted in the salivary secretion of the infected mosquito when, at any time subsequent to the completion of the developmental process, she proceeds to feed on blood. Although the germ of yellow fever as it occurs in the blood may be ultramicroscopic, the analogy of the malaria parasite favours the idea that in the insect it may grow to a visible size, and that although search in the blood for the cause of this grave disease hitherto has proved unsuccessful, it may yet be demonstrated in the tissues of the mosquito. Further, as several species of mosquito of the sub-family *Anophelinæ* have been shown to foster the malaria parasite, it is not improbable that several species of the genus *Stegomyia* may turn out to be effective intermediaries for the germ of yellow fever.*

Symptoms.—There is the same variety in the initial symptoms of yellow fever as in other specific fevers. There may be sudden rigor supervening in the midst of apparent health; there may be only slight chills; or there may be a period of premonitory malaise leading up to the more pronounced symptoms. When fairly started, the procession of events is rapid.

Roughly speaking, and provided there are no complications, an attack of yellow fever is divisible into three stages—1, the initial fever; 2, "the period of calm," as it is called; and 3, in severe cases, the period of reaction.

The initial fever lasts usually from three to four days. The maximum temperature is generally attained within the first twenty-four hours, or by the second day, and, in a case of medium severity, may

* In Africa, *S. afrikana*, *S. argenta-punctata*, *S. sugens*.

rise to about 103° or 104° F. During the three or four succeeding days the mercury slowly sinks to 98° or 99°, the daily fluctuations being seldom more than half to one degree. It occasionally happens that high temperature is maintained for two or three days, and also that the maximum is not attained till the third day; as a rule the thermometer behaves as described, the maximum being reached within a few hours of the onset of the disease.

With or soon after the initial chill or rigor, severe headache sets in, and is generally a prominent feature. For the most part the pain is concentrated about the forehead, in the circumorbital region and in the eyeballs themselves. In many cases it is associated with intolerance of light.

Loin pain is another very distressing symptom; it may amount to positive agony. The legs, too, ache excessively—particularly the calves, knees, and ankles; they feel as if broken. Epigastric pain is generally a prominent symptom.

The face is flushed and swollen; the eyes are shining, injected, and ferrety; the skin is dry.

What with pain and febrile distress, the patient rapidly passes into a very miserable condition. He is restless and continually tossing about.

At first the pulse ranges from 100 to 120, and is full and strong; but as the disease progresses the pulse loses its sthenic character, gradually falling in force and frequency until, at the "period of calm," it becomes remarkably slow and compressible, beating perhaps only 30 or 40 times per minute.

At the outset the tongue is not very dirty, but it soon acquires a white coating on the dorsum, the edges remaining clean. It is not so swollen and flabby as in malarial fever; on the contrary, it is rather small and pointed throughout the disease. This is regarded as an important diagnostic mark; taken along with the progressive diminution in the strength and frequency of the pulse, and the peculiar behaviour of the temperature, it is nearly conclusive as to the disease being yellow fever. Later, the tongue dries, and, at the same time, thirst becomes intolerable.

The palate is congested and swollen; the gums may also swell and bleed.

The congested appearance of the face at the onset of the disease tends to subside: so that by the time the asthenic stage is reached the features may have become shrunken and small, the eyes sunken, and the eyelids discoloured by ecchymoses.

In some cases the skin is hot and dry throughout; in others it may be bedewed with perspiration from time to time; or the sweating may be constant, especially so if collapse sets in.

By the third day the scleræ assume a yellowish tinge, and very often the skin acquires the yellow colour from which the disease derives its name. It must not be understood, however, that every case presents this colour of skin; in some it is entirely absent, but if carefully looked for there is always some yellowness of the scleræ to be discovered. The yellow tinging of the skin generally shows about the end of the first stage, deepening in intensity as the case advances, and remaining apparent for a considerable time after convalescence has become established. It ranges in depth from a light saffron tint to a deep mahogany brown. In fatal cases it is always present; not necessarily during life, but invariably after death. The skin in bad cases is said to emit a peculiar odour like gun washings, or, as Jackson puts it, like the smell of a fish market.

Petechial, erythematous, papular, and other eruptions may show themselves in different cases; but in yellow fever there is no characteristic eruption, unless it be an erythematous congestion of scrotum or vulva, which occurs in a proportion of cases and is said to be diagnostic.

An important feature, from the diagnostic as well as from the prognostic point of view, is the appearance, in some cases almost from the outset of the disease, of albumin in the urine, together with a tendency to suppression. In mild cases these features may be made marked; but in severe cases, particularly during the stage of depression, the urine may fall to a few ounces, and be loaded with albumin to the extent of

one-half or even two-thirds. The more pronounced these symptoms, the graver is the prognosis. Urea (even during the incubation period) and uric acid are very much diminished, the former in severe cases falling to 1·5 grm. to the litre. The urine is almost invariably acid, depositing granular casts, and giving spectroscopic evidence of hæmoglobin. Bile pigments show themselves towards the end of the disease; their appearance is regarded as a favourable omen. Hæmorrhage from kidneys or urinary tract is not uncommon.

Delirium may occur, but is not an invariable feature. Usually, after the initial stage of restlessness and acute suffering, the patient becomes torpid, and perhaps taciturn. In bad cases coma, subsultus, etc., may gradually supervene, the temperature rising as death approaches and even after death.

At the outset the bowels are confined. In the second stage diarrhœa, perhaps of black material resembling the vomit, may supervene; or there may be actual hæmorrhage of bright-red blood from the bowel.

The well-known *black vomit*—always a grave symptom, but fortunately not by any means an invariable one—forms one of the most striking features of this disease. In the earlier stages of the fever vomiting of bilious matters is a common occurrence. This may subside, or, after a time, give place to a coffee-ground vomit which seems to gush up without straining or effort on the patient's part, and which gradually deepens in colour until it becomes uniformly black. On microscopical examination the vomited material is found to consist of broken-down blood corpuscles and altered hæmoglobin suspended in a yellowish mucoid fluid. This material is, doubtless, in the main derived from blood transuded through the walls of the capillaries of the mucous membrane of the stomach. It is intensely acid. Though the black vomit may not always be seen in fatal cases during life, it is invariably found in the stomach on post-mortem examination.

Sometimes pure blood is thrown up from

stomach; similar passive hæmorrhages may take place from almost any part of the body—from eyes, ears, nose, mouth, bladder, uterus, and so on.

Death may occur during the early acute stage, being preceded by a rapid rise of temperature.

In mild cases the "period of calm," which sets in after the subsidence of the initial fever, may last for several days before convalescence is established. In such, recovery once begun is usually very rapid; in a week from the beginning of the disease the patient may be about again. In severe cases, however, the period of calm is followed by a third stage, the stage of reaction, in which the temperature again rises, though not to so high a point as in the initial fever, and a sort of remitting fever of an adynamic type keeps on for several days or weeks. This secondary fever is more prolonged if there is any complication, such as abscess, boils, parotitis, buboes, hepatitis, and so forth. The icterus is now very pronounced; black vomit may recur, or appear for the first time; perhaps a profuse diarrhœa ends in collapse; or the urine may be suppressed, stupor, coma, and other nervous symptoms ensuing, and very often ending in death. In other instances the secondary fever terminates in a crisis of sweating and a prolonged convalescence.

Relapse may occur at any time up to two or three weeks after the subsidence of the initial fever. It is specially prone to occur if the patient has been guilty of any dietetic imprudence during the period of calm—a period at which the appetite may return to some extent. Relapses are very dangerous.

Prognosis and mortality.—Prolonged initial rigors, algidity, convulsions, suppression of urine, coma, hæmorrhages, are all unfavourable symptoms. The prognosis is good if the temperature during the initial fever does not exceed 103° to 105° F. It is better for women (although, if pregnant, abortion is almost invariable) and children than for men; better for old residents than for new-comers; worst of all for the intemperate. According to a table given by Sternberg, of 269 carefully observed cases

there were no deaths in 44 cases in which the temperature did not rise over 103°; per contra, in 22 cases in which the thermometer rose over 106° there were no recoveries. Of 36 in which the temperature rose to between 105° and 106°, 22 died; of 80 with maximum temperatures between 104° and 105°, 24 died; and of 87 in which it ranged between 103° and 104°, only 6 died. The mean mortality in the whole 269 cases was 27·7 per cent. Although in some epidemics it has risen as high as 50 or even 80 per cent. of those attacked, the foregoing may be taken as a fairly representative mortality in yellow fever among the unacclimatized—something between 25 and 30 per cent. Among the permanent inhabitants of the endemic districts the case mortality is very much lower—7 to 10 per cent. During epidemics abortive and ambulatory cases occur; in these, icterus and other characteristic symptoms are often absent. Such cases may be hard to diagnose from febricula or mild malarial attacks. In them the mortality is nil. Some epidemics are particularly mild; in others the majority die. In the same epidemic the cases may vary in severity from time to time. In children the mortality is insignificant.

Pathological anatomy.—Depending probably on hæmoglobin diffused in the liquor sanguinis and tissues, and not on biliary pigment, the yellow colour of the skin is most marked in the dependent parts of the cadaver, especially in those parts which are subjected to pressure. Petechiæ are common in the skin and serous membranes; more considerable extravasations of blood may be found in the muscles. The brain and meninges are hyperæmic, and may be studded with minute hæmorrhagic effusions; like the other tissues of the body, they are stained a lighter or deeper yellow. The blood in the vessels of the general circulation is not firmly coagulated. The blood corpuscles appear to be normal, although there can be little doubt that there is in this disease a liberation of hæmoglobin, arising, possibly, from destruction of a proportion of the corpuscles. An important fact, as explaining the liability to passive hæmorrhages,

is the existence of a generalized fatty degeneration of the capillaries and smaller blood-vessels. The stomach, as stated, always contains more or less black material, sometimes fluid blood, such as may have been vomited during life. The folds of the gastric mucosa are swollen; here and there are arborescent patches of congestion, and ecchymoses. Observers are not agreed as to the nature of this congestion—whether it is passive or inflammatory. Sternberg says that in the increase of leucocytes in the submucosa there is evidence of a slight inflammatory action. The small intestine may contain a dark, acid material similar to that in the stomach, and doubtless coming from the same source. Like that of the stomach, the mucous membrane of the intestine shows patchy arborescent injection.

As compared with other fevers, in yellow fever the liver is characteristically affected. As a rule, if death has occurred at the later stages, this organ is somewhat exsanguine, friable, and presents a yellowish colour from profound fatty changes in the cells. Occasionally, though rarely, it may be hyperæmic and dark. Throughout the gland the cells—particularly those about the periphery of the lobules—on microscopical examination are found to contain globules and grains of fat. The nuclei in some instances, as well as the protoplasm of the cells, show fatty changes; the latter may be completely disintegrated. In the great majority of cases this fatty degeneration is well marked. It is not confined to the liver; every organ of the body is more or less affected in the same way.

The spleen is not characteristically affected, but the kidneys show signs of parenchymatous nephritis. Hæmorrhagic foci under the capsule and in the cortex are common. The renal epithelium shows cloudy swelling passing on to fatty degeneration and desquamation. The tubules, here and there, are filled with infarcts, either of an albuminoid material or of débris of desquamated epithelium, corresponding with the numerous casts which can be discovered in the albuminous urine.

Diagnosis.—The diagnosis of yellow fever is treated of in one of the chapters on malaria and in that on blackwater fever (*see* pp. 114, 298). Practically, the only two diseases with which severe yellow fever is likely to be confounded are bilious remittent and hæmoglobinuric fever. The difficulties of diagnosis are often very great; particularly so in the earlier cases of an epidemic. When several deaths, preceded by fever and black vomit, have occurred within a limited area and in quick succession, a suspicion of yellow fever becomes a certainty. There is no clinical feature, so far as is known, which would distinguish a mild attack of yellow fever from an ordinary febricula, nor any pathognomonic clinical sign that would absolutely distinguish a malarial remittent from yellow fever. Probabilities must be weighed in diagnosis when it is based on clinical grounds alone. The only reliable guides are the discovery of the malaria parasite and the characteristic pigment and leucocytic variation in malarial fever, and the determination of their absence in yellow fever; and, when cases come to the post-mortem table, the presence of pigment in the viscera in the former, and of extensive fatty degeneration of the liver cells in the latter.

Treatment.—Formerly a much more active treatment than that in vogue at the present day was the fashion for yellow fever. It is now recognized that, as with most specific fevers, the treatment is more a matter of nursing than of drugs.

Experience has shown that a smart purgative at the very onset of the disease is beneficial. With many castor oil is the favourite drug, but to be of service it has to be given in very large doses—2 to 4 oz. Others use calomel; or calomel combined with quinine—20 gr. of each. Others, again, prefer a saline. The purgative, whichever be selected, must not be repeated, nor, for that matter, given at all if the patient is not seen until after the second day of the disease.

Hot mustard pediluvia, frequently repeated during the first twenty-four hours, the patient and

bath being enveloped in a blanket, are much in favour. They are said to relieve the cerebral congestion and the intense headache. Very hot baths, with subsequent blanketing and sinapisms to the epigastrium, are also said to have a similarly favourable influence on the congestion of the stomach which is, undoubtedly, another constant feature of the disease. For high fever, antipyretic drugs, cold baths, iced injections, cold sponging, and the like may be carefully employed. In view of the asthenic nature of the disease, the less depressing measures should be preferred.

Vomiting may be treated with sinapisms and ice pills, or with small doses of cocaine. Morphia is dangerous, and must be avoided. For black vomit, frequently repeated doses of perchloride of iron, ergotine injections, acetate of lead, and other styptics have been recommended. For restlessness, phenacetin or antipyrin is used. When the skin is dry, the urine scanty, and the loins ache excessively, Sternberg recommends pilocarpine.

After the fourth or fifth day the flagging circulation demands stimulants of some sort. Iced champagne, hock, or teaspoonful doses of brandy given every half-hour may tide the patient over the period of collapse. Great care, however, should be exercised in the use of these things; if they seem to increase the vomiting and the irritability of the stomach, they must be stopped at once.

The feeding is an important matter. So long as there is fever the patient has no appetite; during this time—that is, for the first two or three days—he is better without food. When the fever subsides appetite may return, and a craving for nourishment become more or less urgent; the greatest care, however, must be exercised about gratifying this untimely appetite. Only the blandest foods, and these only in very small quantities, should be allowed—such as spoonfuls of iced milk or chicken tea. Gradually the quantities may be increased; but, even when convalescence is established, solid food must be partaken of very sparingly, and it must be of the

simplest and most digestible description. Indiscretion in eating is a fruitful cause of relapse in yellow fever; and it must be borne in mind that in this disease relapse is exceedingly dangerous. Nutrition may be aided by nutrient enemata.

The Sternberg treatment.—Sternberg has introduced a system of treatment by alkalis which promises well. It is directed principally to counteracting the hyperacidity of the gastric and intestinal contents—always a marked feature in yellow fever. His prescription is 150 gr. of sodium bicarbonate and $\frac{1}{3}$ gr. of mercury perchloride in a quart of water; of this $1\frac{1}{2}$ oz. is given every hour. This, he claims, not only neutralizes the acidity of the intestinal contents but increases the flow of urine, the perchloride of mercury tending to check fermentation changes in the alimentary canal. Of 301 whites treated in this way only 7·3 per cent. died, and of 72 blacks all recovered. Other encouraging figures have been adduced as to the efficacy of this line of treatment, which is certainly deserving of further and more extended trial.

Prophylaxis.—It is the duty of sanitary authorities in tropical countries, so far as possible, to free of mosquitoes the areas over which they have charge. If this were effectually done everywhere there would be no malaria, no filariasis, and no yellow fever. Although complete extermination of mosquitoes is not to be expected, relative extermination of mosquitoes is worth attempting, and certainly much can be attained in this direction by the vigorous use of the now well-known measures. In Havana, by such means, in a very few months the number of mosquitoes was reduced 90 per cent., with, doubtless, a corresponding gain to the community in the diminution of mosquito-conveyed disease. The same has happened in Panama, Rio, and elsewhere.

During epidemic visitations or during exacerbations of endemic yellow fever, non-immunes should, if possible, immediately quit the implicated locality. Above all, the slums and low-lying districts of the town should be shunned. These places should not

even be visited; or, if visits have to be made to them, they should be as brief as possible, and not made after sundown. The susceptible should not sleep in the lower storeys of houses, and should pay great attention to general health, carefully avoiding all causes of physiological depression or disturbance. Sailors must not be allowed on shore.

In every country subject to visitations of this disease the sanitary condition of the towns should be most carefully attended to, especially as they refer to the stegomyia mosquito. All water-tanks and cisterns must be effectually screened by fine-meshed metallic gauze; all puddles and stagnant water abolished; all cases of any kind of fever, no matter how mild they may be or what their nature, must be reported at once to the central sanitary authorities, who should have full powers promptly to screen or otherwise deal with them and the houses in which they are. Delay in recognizing the earliest cases of a threatened epidemic, as shown by experience in New Orleans, is most dangerous, leading, as it may, to the rapid multiplication of infected centres.

Ships should not be allowed to clear from infected ports, nor to enter non-infected ports during the warm season, without adequate inspection. If, on entering port, yellow fever is found on board, the cases should be isolated in a quarantine hospital where there are no stegomyia mosquitoes, the ship thoroughly cleared of mosquitoes, and the passengers and crew prevented for at least five, better thirteen, days from communicating with the shore, or until every risk of conveying infection has passed away.

In the event of the disease appearing in a locality which is not habitually a yellow-fever centre, and of which the population is small, an economical plan of dealing with the threatened danger is for the authorities promptly to remove the entire population of the neighbourhood, with the exception of the insusceptible and those in attendance on the sick, and to place the deported population, before dispersion, in a thirteen days' quarantine camp. Mean-

while the infected area must be rigidly isolated and its mosquitoes destroyed. In this way the spread of the disease will be prevented.

In the event of yellow fever breaking out in the crew of a man-of-war, the cases, if possible, should be sent ashore, and the ship hurried north or south into cold weather, any mosquitoes which may have found their way on board being at once destroyed.

In the case of the appearance of yellow fever in a large town, the method which was so successfully adopted by Surgeon-General Gorgas, U.S.A., must be adopted. Funds and authority must be obtained at once. An efficient and adequate sanitary staff must be promptly organized and instructed in their duties. Cases of every kind of fever as well as cases of yellow fever should be immediately reported, and the patients promptly protected from mosquito bite by wire screens. At the same time the systematic destruction of mosquitoes in their breeding-places and in the patients' and neighbouring houses must be rigidly enforced. The infected houses should be carefully sealed up by pasting paper over all the doors, windows, ventilators, chimneys, and cracks, and the fumes of pyrethrum or of burning sulphur—2 lb. per 1,000 cubic feet of space—or other insecticide employed to stupefy the insects, which should afterwards be swept up and burned. In this way, in 1901, yellow fever was stamped out in ninety days in Havana, a city where for a period of 140 years it had held uninterrupted sway. In this way, in 1905, New Orleans was freed from the disease in a much shorter period than in any previous epidemic; and in this way Gorgas has made the line of the Panama Canal as healthy as New York. Similar results from similar measures are being obtained in the larger Brazilian ports.

Guiteras has shown, in a practical manner, that yellow-fever patients may be admitted to the wards of a general hospital or be nursed in private houses with impunity, provided they are protected by effective mosquito netting from mosquito bite during the first three or four days of their illness.

Portability of the virus in fomites and merchandise.—Until recently it was universally believed that the virus might remain for a considerable time potentially infective in fomites, clothes, merchandise, etc., and in wooden structures (ships). Thus, Strain describes an epidemic in São Paulo in which he believed the initial cases acquired the infection from unpacking a box of clothes which had lain at Santos for some time and had been damaged there by damp and sea-water. The epidemic of 1893 in the same city he traced to certain cases of machinery which had lain for some months at Santos. On opening the cases the packing straw was found to be damp. Four of the people in the house where the cases were opened got yellow fever within a few days.

Many similar instances have been adduced as conclusive evidence of the portability of the virus of yellow fever in fomites. But the very thorough and carefully conducted experiments carried out in Cuba by Drs. Reed, Carroll, and Agramonte go far to prove that fomites have nothing whatever to do with the conduction of the disease. A small, ill-ventilated, badly lighted wooden hut was erected near Havana during the prevalence of epidemic yellow fever. The fresh and stale fomites of yellow-fever patients, in the shape of soiled bedding, clothes, black vomit, etc., were strewn about or stowed away in great profusion in this close hut, and among them, lying on beds that had been occupied recently by yellow-fever patients, wearing these patients' soiled night-clothes and using their soiled blankets, seven non-immunes (that is, white men, recently arrived and never previously affected with yellow fever) slept during, in the aggregate, sixty-three nights—from November 20th, 1900, to January 31st, 1901—with absolute impunity.

Immunity of the native as affected by anti-stegomyia sanitation.—The immunity of the native of the endemic areas of yellow fever is usually attributed to a mild attack in childhood. If yellow fever has been exterminated from Havana and

other endemic centres by anti-stegomyia and other measures, the children in these places can no longer be attacked by the disease. It follows that, in the course of one generation, the entire population will become non-immune. Doubtless sooner or later the germ of yellow fever will be introduced again, and then, having a population entirely non-immune to spread in, unless promptly checked, a far more extensive epidemic than ever devastated these places in less scientific days will ensue. This can be confidently predicted if it be true that the present immunity of the native depends on an attack of ordinary yellow fever in childhood. I am inclined to think that this explanation does not cover the entire ground; for, if the disease be so mild in childhood as not to be recognizable, how was it that Gorgas stamped out yellow fever in Havana, and how is it that the disease is not in evidence there now? I would suggest that there are two strains of yellow-fever virus—one of great virulence, one of little virulence. Specifically the same, they are mutually protective, much in the same way as with vaccinia and smallpox. The immunity of the native and the old resident I would attribute to epidemics or endemics of the mild strain of yellow fever, which, could it be recognized clinically, might be used as a vaccine against the more virulent disease.*

Introduction of yellow fever into Asia.—There is another important matter in connection with this disease which, in the near future, ought to be made a subject for international consideration. I refer to the possibility of the spread of yellow fever to Asia, the Eastern Archipelago, Polynesia, and East Africa. It has spread in the past to Europe;

* Thomas has communicated yellow fever to the chimpanzee; possibly to the guineapig. Doubtless there are other lower animals susceptible to the infection. A passage through one of these may deprive the germ of its virulent pathogenic properties. The omnipresent stegomyia would be an active vaccinator of the non-virulent strain, passing it from native to native, and so rendering them immune against the virulent form of the disease. At all events, until proof is adduced that something of this sort does not occur, the possibility that it does occur should not be ignored.

this is a comparatively unimportant matter, as the climatic and hygienic conditions in that continent are not favourable to the stegomyia mosquito, and therefore to the extension of the disease. It is otherwise in this respect, it is to be feared, with Asia. Fortunately, yellow fever, so far as known, has never appeared in the crowded, filthy cities of the East; but, should it ever be introduced there, the favourable climatic conditions, the surpassing filth everywhere, the presence of stegomyia mosquitoes, and the too frequent absence of efficient sanitary machinery will enable it to spread like wildfire in an entirely non-immune population. The probable reason of its non-introduction into Asia is that the trade route from the West Indies and Central America to China and India has hitherto not been a direct one, but has passed by a long circuit either to the north or to the south. When the American interoceanic canal is in use there will be direct and rapid communication between the present yellow-fever centres and Asia. With this more direct and more rapid communication there will arise a corresponding risk of spreading yellow fever into a huge section of tropical humanity which has hitherto enjoyed exemption from one of the deadliest diseases afflicting mankind. An infected mosquito (and *Stegomyia calopus*, according to Giles, is a good traveller), either shipped by accident or brought on board by some thoughtless or malicious person, could easily be conveyed alive to the shores of Asia, and would suffice to set, so to speak, the whole of the tropical section of the Eastern hemisphere in a blaze. The history of the spread of disease by the rapid methods of modern travel is full of examples that should serve as a warning to our rulers and responsible sanitary authorities. Let us hope that before the Central American Canal is completed this important matter will receive the attention it demands, and that due care will be exercised that America does not reciprocate the introduction of cholera from Asia by a return gift of yellow fever.

Stegomyia calopus (fasciata), ♀.

PLATE VII.

GENUS STEGOMYIA

The members of this group of mosquitoes, belonging to the sub-family *Culicinæ*, present very distinctive characters. Their ova, instead of being cemented together to form rafts as in other *Culicinæ*, are deposited separately, each being surrounded by small air-chambers. Their larvæ are somewhat elongate, with rudimentary antennæ, and a short stout siphon; they maintain an almost vertical attitude. In the nymphæ the trumpets are expanded and broadly triangular in shape. The imago exhibits a distinctive scale structure and, at all events in early life, observes diurnal habits.

The *Stegomyiæ* are easily recognized by the broad, flat, imbricated scales which completely cover the head and abdomen and which are invariably present on the middle lobe and frequently also on the lateral lobes of the scutellum. These scales give to the insect a satin-like appearance which is quite characteristic. They are mostly small, black insects, with white, silvery, or yellow lines, bands, or spots on the thorax and legs. In India they are known as "tiger mosquitoes" on account of their striped appearance. They seem to have a decided preference for the littoral, and certain species (*S. calopus*, *S. scutellaris*) are frequently found on ships and are doubtless distributed by this means. At present the genus *Stegomyia* includes nineteen species, all of which are easily identifiable on account of their striking thoracic and other ornamentation. Of these the type species, *S. calopus*, is the most important on account of its wide distribution in all tropical and sub-tropical countries, and of its share in the propagation of yellow fever.

S. calopus (Plate VII.) can be recognized by the peculiar lyre-shaped ornamentation of its thorax, composed of two dull yellow parallel lines in the middle and a curved silvery line on each side.* The proboscis is not banded; the abdomen is banded basally; the last hind tarsal joints are all white, and some of the other tarsal joints are marked by light bands basally. This widely distributed species is essentially a domestic form and bites with avidity. It breeds in small artificial collections of water, such as barrels, puddles, cisterns, and even in such small receptacles as sardine tins. The nature of the water appears to be a matter of indifference. The eggs resist a considerable degree of desiccation, and, as they may sink to the bottom of the water in which they lie, are readily pumped into the water-tanks of ships.

Although widely distributed, *S. calopus* does not occur abundantly in certain parts, such as the Malay States, China, and Africa, where its place is taken by closely allied species such as *S. scutellaris* in the Malay States, China, etc., and *S. africana*, *S. argenta punctata*, and others in Africa. It is quite possible that, besides *S. calopus*, other species belonging to the genus may be able to transmit the yellow-fever germ.

* This ornamentation is constant, but the median thoracic stripes are absent in a variety called *S. fasciata mosquito*.

CHAPTER XIV

DENGUE *

Definition.—A specific fever of warm countries, occurring usually as a rapidly spreading epidemic and, in typical cases, characterized by a suddenly developed primary fever of about three days' duration, succeeded by a period of apyrexia—actual or relative—and this again by a milder secondary fever accompanied by a rubeoloid eruption. Throughout the febrile stages, and often subsequently, severe rheumatic-like pains are a prominent symptom. The disease in its active form lasts about a week and is attended with little, if any, mortality.

Geographical distribution and mode of spread.—Most parts of the tropical world have been visited at one time or another by dengue. From a study of the dates of the various epidemics, it would seem that there is a tendency for it to assume pandemic characters about once in every twenty years. Perhaps of all places in the world it is most frequently met with in the West Indies.

Recently dengue has appeared in Syria, Asia Minor, on the Ægean shores of Greece and Turkey, and in North Queensland, Australia. Early in the last century it was seen in America, as far north as Charleston and Philadelphia in the United States, and as far south as São Paulo in the Brazils.

Like other specific communicable diseases, dengue tends to advance along trade routes and lines of communication. Thus, starting from Zanzibar, the epidemic of 1870–73 first reached Aden. Thence it travelled to Suez on the one side and to India on the other.

* According to Hirsch, the word "dengue" is derived from the Spanish equivalent of our word "dandy." The disease has received many names, such as "scarlatina rheumatica," "break-bone fever," etc.

Passing to Singapore, it followed the trade routes to Cochin China and China, spreading at the same time to the islands of the Eastern Archipelago. From India it was carried by the coolie ships to Mauritius and Réunion in 1873.

An epidemic which I witnessed in Amoy (1872) illustrated very well a characteristic feature of dengue epidemics—namely, the peculiar suddenness of their rise and extension, and the general prevalence of the disease in an affected community. I am under the mark when I say that in this particular epidemic quite 75 per cent. of natives and foreigners were attacked within a very few weeks. All ages and occupations, both sexes, and people in every condition of life, were alike subject to it. About the first week in August I heard that a peculiar disease had appeared in the town; by the end of the second week the cases were numerous, whole families being prostrated at a time. A week later the cases were still more numerous, and by the end of the month so general was the disease that the business of the town was seriously interfered with. By the end of the following month —that is to say, in about eight weeks from the first appearance of the epidemic—all the susceptible apparently had passed through it, and, so far as Amoy residents were concerned, the disease was at an end, cases occurring for a few weeks longer only in visitors from unaffected districts. This course seems to be fairly typical of all dengue epidemics.*

Etiology. *Germ.*—Various bacteria have been described. Graham describes an intracorpuscular amœba, resembling *Babesia bigemina*, which he states he found in great profusion in the blood of

* It is on my experience in this epidemic that I have based my description of dengue. In the vast majority of the cases the characteristic primary and secondary fevers, the initial and terminal skin rashes, and the rheumatic-like pains were well marked. Of course, as with all specific fevers, there was a proportion of atypical cases in which some of the characteristic symptoms were absent or only slightly marked. Remembering my experience of this epidemic, I cannot understand the difficulty some recent Indian observers seem to have in differentiating dengue from seven-days' fever and the like. The skin rashes alone should suffice, especially if taken in conjunction with the double fever and the pains.

dengue patients in Beyrout, Syria. He maintains that his experiments tend to show that, like yellow fever, dengue is communicated by a mosquito, *Culex fatigans*. Acting on this hypothesis he was able to protect families from dengue by means of mosquito nets. Ross is said to have extinguished the yearly epidemics in Port Said by anti-mosquito measures. Bancroft, who considers that the germ is ultramicroscopic, has advanced the same view in Australia in favour of *Stegomyia fasciata*. Recent experiments by Ashburn and Craig, made under favourable conditions, seem to show that the germ of dengue resides in the liquor sanguinis, that it is ultramicroscopic and therefore unfilterable, that injected into non-immunes it gives rise to typical dengue, that under natural conditions it is transmitted by *Culex fatigans* through the salivary glands, that the incubation period of the experimental disease is from three to fourteen days, and that it is not contagious in the ordinary sense of that word. In these and in some other respects dengue has a striking parallelism to yellow fever.

Influences of meteorological conditions.—When dengue spreads beyond its ordinary tropical limits, as, for example, in the epidemics of Philadelphia and Asia Minor, the extension occurs only during the hottest part of the year—in the late summer and early autumn. Hitherto such epidemics have been arrested on the approach of winter. Even when occurring within the tropics, dengue prevails principally, though not exclusively, during the hottest part of the year. High atmospheric temperature, therefore, seems to be one of the conditions it demands.

Epidemics occur indifferently during the dry or the rainy seasons, the hygrometric condition of the atmosphere being without manifest influence.

Usually a coast disease.—It would appear that dengue, like yellow fever, prefers the coast line and the deltas and valleys of great rivers to the interior of continents. There are many exceptions to this rule; in 1870–73 it spread all over India. The distribution and concentration of population on the seaboard and along rivers, the freedom of com-

munication between communities that are so located, and the mosquito conditions probably determine this preference.

As a rule, elevated places enjoy a relative immunity; if the disease is introduced into such localities, it does not spread. To this, again, there are exceptions, for the Syrian epidemic referred to prevailed in certain spots 4,000 to 5,000 feet above the sea. In the Mediterranean basin dengue is a disease of autumn months and generally follows the summer outbreak of phlebotomus fever.

The **incubation period** seems to be somewhat variable. It is certainly not a long one. I have seen a case in which it could not have exceeded twenty-four hours. Some observers place it at five and even seven days; this, I feel sure, is an over-estimate. One to three days seems to be near the truth.

Symptoms. *Initial fever and eruption.*—An attack of dengue may be preceded for a few hours by a feeling of malaise or, perhaps, by painful rheumatic-like twinges in a limb, toe, finger, or joint. Usually it sets in quite suddenly. A patient, describing his experience, said that in the morning he got up feeling quite well, but before he could complete his dressing he was so prostrated by pain and fever that further exertion was impossible, and he had to crawl back to bed again. Similar stories, illustrative of the sudden incidence of the symptoms, circulate during every epidemic of dengue. Sometimes the fever is ushered in by a feeling of chilliness or even by a smart rigor; sometimes a deep flushing of the face is the first sign of the disease.

However introduced, fever rapidly increases. The head and eyeballs ache excessively, and some limb or joint, or even the whole body, is racked with peculiar stiff, rheumatic-like pains, which, as the patient soon discovers, are very much aggravated by movement. The loins are the seat of great discomfort, amounting in some cases to actual pain; the face—particularly the lower part of the forehead, round the eyes, and over the malar bones—may become suffused a deep purple; and often the skin over part or the

whole of the body, and all visible mucous surfaces, are more or less flushed, that of the mouth and throat being sore from congestion and perhaps from small superficial erosions. The eyes are usually much injected; very often the whole face is bloated and swollen. This congested erythematous state of the skin constitutes the so-called initial eruption.

These symptoms becoming in severe cases rapidly intensified, the patient, in a few hours, is completely prostrated. His pulse has risen to 120 or over; his temperature to 103° F., in some cases to 105°, or even to 106°. He is unable to move owing to the intense headache, the severe pain in limbs and loins, and the profound sense of febrile prostration. From time to time the skin may be moistened by an abortive perspiration, but for the most part it is hot and dry. Gastric oppression is apt to be urgent, and vomiting may occur. Gradually the tongue acquires a moist, creamy fur which, as the fever progresses, tends to become dry and yellow.

Defervescence.—In this condition the patient may continue from one to three or four days, the fever declining somewhat after the first day. In the vast majority of cases this, the first and most acute stage, is abruptly terminated about the end of the second day by crisis of diaphoresis, diarrhœa, diuresis, or epistaxis. When epistaxis occurs the relief to the headache is great and immediate. On the occurrence of crisis the erythematous condition of the skin, if it has not already disappeared, rapidly subsides. In a proportion of cases, and particularly in certain epidemics, crisis does not occur, the fever slowly declining during a period of three or four days. Thus the urgent symptoms abate, and the patient rapidly, or more slowly, passes from what, in many cases, may be described as the agony of the first stage to the comparative calm and comfort of the second.

The interval.—When the second stage is established and the thermometer has sunk to normal, the patient is sufficiently well to leave his bed and even to attend to business. An occasional twinge in leg, arm, or finger, or a tenderness of the soles

of the feet, and perhaps giddiness in walking, may remind him of what he has gone through and warn him that he is not quite well yet. But the tongue cleans, and the appetite and sense of well-being return to some extent.

Terminal fever and eruption.—This state of comparatively good health continues to the fourth, fifth, sixth, or even to the seventh day, counting from the commencement of the illness. Then there is generally a return of fever, slight in most cases, more severe in others. It is usually of very short duration—a few hours. Sometimes this secondary fever does not occur; probably it is often overlooked. With the recurrence of the fever an eruption of a rubeolar character appears. The pains likewise return, perhaps in more than their original severity. Though the fever subsides in a few hours, the eruption, at times very evanescent, may keep out for two or three days longer, to be followed very generally by an imperfect furfuraceous desquamation. It seldom happens that the fever or pains at this stage keep the patient in bed, although that is the best place for him if a comfortable and speedy convalescence is desired. Rarely, in this secondary fever, does the thermometer rise to 103° F. The temperature falls rapidly to below normal on the setting in of diaphoresis, or diarrhœa, or of some form of crisis.

Characters of the eruption.—The terminal eruption of dengue possesses very definite characters. It is absent in a very few cases only; in many of those cases in which it is supposed to be absent, being slight, it is overlooked. As stated, the eruption is rubeolar in character. It usually commences on the palms and backs of the hands, extending for a short distance up the forearms. Its development is often associated with sensations of pricking and tingling. On the palms of the hands the spots are at first about the size of a small pea, circular, dusky red, and sometimes slightly elevated. The eruption quickly extends, and is best seen on the back, chest, upper arms, and thighs. In these situations it appears at first as isolated, slightly elevated, circular, reddish-

brown, rubeoloid spots, from one-eighth to one-half of an inch in diameter, thickly scattered over the surface, each spot being isolated and surrounded by sound skin. After a time the spots, enlarging, may coalesce in places; thus irregular red patches from 1 to 3 in. in diameter are formed. Or perhaps there is a general coalescence of spots, isolating here and there patches of sound skin; in this case the islands of sound skin give rise, at first sight, to the impression that they constitute the eruption—a pale eruption, as it were, on a scarlet ground. In a few instances the whole integument may be covered with one unbroken sheet of red. The rash is usually most profuse on the hands, wrists, elbows, and knees; in these situations it is generally coalescent, and there, too, it may be detected though absent elsewhere. The spots disappear on pressure, and never or rarely become petechial. They fade in the order in which they appear—first on the wrist and hands; then on the neck, face, thighs, and body; last on the legs and feet.

Desquamation.—Desquamation may go on for two or three weeks. In many it is trifling in amount; for the most part it is furfuraceous. Rarely does the epidermis peel off in flakes of any magnitude; never in the broad sheets seen after scarlatina. Often for a day or two desquamation is accompanied by intense pruritus.

Convalescence.—In some instances, and in some epidemics, the disease terminates with the fading of the eruption; appetite and strength gradually return, and the patient, after a few days of debility, feels well again. Bradycardia may persist for a time.

The rheumatoid pains.—With most, their troubles do not end so soon. For days or weeks some muscle, tendon, or joint is the seat of the peculiar pains, which may become so severe as to send their victim back to bed again. Sometimes, three or four weeks after all apparent trace of the disease has vanished, a joint or a muscle will be suddenly disabled by an attack of this description. This may occur in patients who, during the acute stage, suffered little or no pain. A finger or toe, or a joint of a finger or of a toe, may

alone suffer. Of all the joints, perhaps the knee is most frequently affected; but wrists or shoulders are often attacked, and their associated muscles may even undergo considerable atrophy from enforced disuse. The soles of the feet, too, and the tarsal articulations are favourite sites.

The pains of dengue—those occurring during the initial fever as well as those that may be regarded as sequelæ—are difficult to locate with precision; the joints or muscles affected may be percussed, pressed, or moved with impunity. Du Brun locates those associated with the knee in the thigh muscles, which, he says, are painful on deep pressure.

The pains are worst usually on getting out of bed in the morning, and on moving the affected part after it has been at rest for some time. They are relieved somewhat by rest and warmth. Passive movements are, as stated, not painful, but any resistance to the movement of the limb may cause acute suffering. When a muscle is affected the pain is accompanied by a sense of powerlessness.

Other complications and sequelæ.—Convalescence may be very much delayed by the persistence of these pains; also by anorexia, by general debility, mental depression, sleeplessness, evanescent feverish attacks, by boils, urticarial, lichenoid, and papular eruptions, and by troublesome pruritus. Among sequelæ and complications may be mentioned enlargement of the lymphatic glands (particularly the superficial cervical), orchitis, possibly endocarditis and pericarditis, hyperpyrexia, purpura, and hæmorrhages from the mouth, nose, bowel, and uterus. Miscarriage is rare. The urine sometimes contains a trace of albumin, but true nephritis does not occur.

Variability of epidemic type.—Judging from the published descriptions, there is considerable variety in the symptoms of this disease in different places and in different epidemics. Some authors mention swelling and redness of one or more joints as a common and prominent symptom; others refer to metastasis of the pains, enlargement of submaxillary glands, orchitis, mental depression, hæmorrhages, and so forth, as

being frequently present. However this may be, the essential symptoms in well-marked cases are the same practically everywhere, and in all epidemics; these are, suddenness of the rise of temperature, an initial stage of skin congestion, limb and joint pains, and a terminal rubeoloid eruption.

Relapses are not uncommon in dengue, and second and even third attacks during the same epidemic have been recorded. As a rule, however, susceptibility to the disease is exhausted by one attack. According to Hare, in a recent Australian epidemic the immunity acquired by an attack did not persist beyond one year.

Mortality.—In uncomplicated dengue the mortality may be said to be almost nil (0·1 per cent., Hare). In the case of very young children, convulsions and delirium may occur and cause anxiety; and in the aged and infirm, and in those suffering from chronic exhausting disease, an attack of dengue may prove a serious complication. Charles describes a pernicious form which, though rare, was very much dreaded in Calcutta. In these cases the lungs became œdematous, and the patient, growing drowsy and cyanotic, rapidly passed into a comatose condition with a tendency to hyperpyrexia, and died. Some writers state that the gravity of any given case is in direct proportion to the abundance of the eruption; others deny this.

In Europeans an attack of dengue very often leads to a condition of debility necessitating temporary change of climate, or even return to Europe. In both Europeans and natives the attendant lowering of the resisting powers predisposes to other and more dangerous diseases, such as malaria, dysentery, phthisis, and so forth; consequently dengue, otherwise a benign disease, may become a source of public danger. It is probable that it is in this indirect way that the general mortality is increased during a visitation of this disease, as has been observed in several epidemics.

Morbid anatomy.—On account of the low mortality, post-mortem records are few. Nogué, who

observed two epidemics of dengue in Cochin China (1895–96), made four post-mortem examinations in this disease. In these, pulmonary and intracranial inflammation were the special features. The meningitis amounted to adhesions and sero-purulent infiltration of the pia mater.

Diagnosis.—Dengue must not be confounded with yellow fever, rötheln, scarlatina, measles, syphilitic roseola, influenza, cerebro-spinal meningitis, seven-days' fever, rheumatic and malarial fevers. A knowledge of the distinctive features of these diseases, and the fact that dengue is attended with a rash and with articular pains, and that it occurs in great and rapidly spreading epidemics, should prevent any serious error in diagnosis. According to Ashburn and Craig, there is a well-marked leucopenia in dengue averaging 3,800 per c.mm., with relative increase of the small leucocytes. This in some circumstances may prove an aid to diagnosis.

Treatment.—Were it possible to secure perfect isolation for the individual during an epidemic of dengue, doubtless he would escape the disease. Even comparative isolation is attended with diminished liability. In Amoy, in the epidemic of 1872, those foreigners who lived in a more or less isolated suburban situation were very much less affected than were those who lived in the native town, or than those whose occupations threw them much into contact with the natives. But, though this and similar facts point to the theoretical possibility of avoiding dengue during an epidemic, in the ordinary conditions of life in the tropics prophylactic measures for the mass are impracticable. Specially delicate individuals, particularly the subjects of tubercular or renal disease, should be isolated, or, better, should leave for a time the epidemic locality.

Like the allied fevers, dengue runs a definite course; therefore it is useless to attempt to cut it short. The patient should go to bed so soon as he feels ill, and he should keep his room till the terminal eruption has quite disappeared and he feels well again. Ten days is not too long to allow in severe

attacks. As in influenza, light liquid diet, rest, and the avoidance of chill conduce powerfully to a speedy and sound convalescence. At the outset of the fever some saline diaphoretic mixture, with aconite, may be prescribed with advantage. If the pains be severe and the fever high, antipyrin, or phenacetin, or belladonna will give great relief. Cold applications to the head are comforting. If the temperature rises to 105° F. or over, cold sponging or the cold bath ought to be had recourse to. If the pains continue very distressing, a hypodermic injection of a minute dose ($\frac{1}{10}$ gr.) of morphia will afford welcome relief and do no harm. Purgatives and emetics should be avoided unless pronounced constipation, or a history of surfeit, urgently demands their exhibition. The pain caused by the muscular movements entailed by the efficient action of purgatives more than counterbalances any advantage the latter might otherwise bring. Wine in the early stage is not advisable. Freshly made lemonade, or iced water, will be found acceptable drinks during the fever.

For the pains experienced during convalescence, rubbing with opium or belladonna liniment, gentle massage, electricity, salicylates, small doses of iodide of potassium and quinine, have been advocated. Debility, or anorexia, indicates tonics such as quinine, strychnine, mineral acids, or vegetable bitters, and change of air.

CHAPTER XV

PHLEBOTOMUS FEVER

Definition.—A specific fever of short duration and no mortality, caused by a germ—ultramicroscopic—introduced by the bite of the sand-fly (phlebotomus).

History.—This disease has been recognized clinically for upwards of a century and described under a variety of local names; but its definite relation to its transmitting agent, although suspected by McCarrison (if his three days' fever of Chitral be the same) in 1903 and by Taussig in 1905, was not established till 1908, when Doerr published his observations of the infectivity of the blood in this form of fever and the rôle of the sand-fly as transmitter. Doerr's conclusions have been confirmed by numerous observers in Malta and elsewhere around the Mediterranean, including Kilroy. Kilroy exposed himself for five nights to the bites of sand-flies on Suda Island, where these insects are particularly abundant and where phlebotomus fever is prevalent; subsequently, at the end of the first day of his fever, he injected his blood into a healthy man and thereby communicated the disease.

Geographical and seasonal distribution.—The range of phlebotomus fever is probably co-extensive with that of the insect transmitter. In the tropics it may break out at any time as an epidemic amongst new arrivals; in the sub-tropics it occurs only or principally during the summer and early autumn. Where the phlebotomus is absent, e.g. Bermuda (Birt), the fever is not found. In some phlebotomus-haunted places as many as 50 per cent. of new-comers are attacked.

Etiology.—The germ resides in the blood of the patient during the first day or two of the fever. It is ultramicroscopic, passing through filters

which arrest *Micrococcus melitensis*. According to Doerr it is transmitted hereditarily through the egg and larva of phlebotomus to the imago; this, however, has not been firmly established experimentally.

Representatives of the genus Phlebotomus are to be found in most tropical and sub-tropical countries. The various species are usually designated "sand-flies." They are exceedingly minute, very delicate, yellowish, greyish, or brownish, somewhat slenderly built insects that bite principally during the night and

Fig. 62.—Female phlebotomus. (*After Alcock.*)

that can pass easily through the meshes of an ordinary mosquito net. At rest the wings are uplifted. The legs are long and slender; the wings, body and antennæ are thickly covered with short hairs. The joints of the antennæ are constricted. The proboscis is as long as the head. The tips of the piercing apparatus (which in other respects resembles that of the mosquito) project beyond the labium. The leaf-shaped wings are somewhat narrow and show all three branches of the second longitudinal vein very distinctly. (Fig. 62.)

P. papatasii (the species on which Doerr's observa-

tions were made, hence one of the names for the disease, papatasii fever) lays about forty eggs, selecting for the purpose damp localities such as the walls of cellars, of latrines, cesspools, crevices in walls, caves and embankments. The cycle of egg, larva and imago takes about one month in warm and upwards of two months in cooler weather to complete. The duration of the life of the imago is not known. It is difficult to keep it in captivity; under such conditions it rarely lives as long as fifteen days.*

There has been much confusion in the nomenclature of the various species of phlebotomus, and it has not been determined which of them, other than *P. papatasii*, convey the infection.

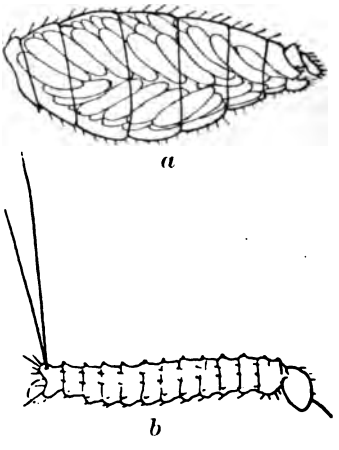


Fig. 63.—*a*, Abdomen of female phlebotomus, showing eggs; *b*, young larva of phlebotomus. (*After Alcock.*)

Pathology.—Yellow fever, dengue and phlebotomus fever have several important points in common, a circumstance suggestive of the possibility of a common or, at all events, a similar origin. Each is transmitted by an insect; their germs occur in the blood-stream and are ultramicroscopic; they are diseases of warm climates only; and, clinically, they are characterized by a short incubation period, a short and rapidly developed fever which is usually associated with relatively slow pulse and leucopenia, with relative decrease of the polynuclears. It would be interesting to ascertain if these diseases are mutually protective.

* Lately, Wenyon has succeeded in keeping these insects alive as long as fifty days.

Unlike yellow fever, but like dengue, phlebotomus fever is rarely or never fatal, so that the morbid anatomy, if there be any, is unknown.

Symptoms and treatment.—These are the same as in McCarrison's three-days' fever of Chitral, to the account of which the reader is referred (p. 380).

Characters of the Genus Phlebotomus

Small hairy flies from 1·5–2·5 mm. in length, easily recognized by their form and thick hairy coat. The females only suck blood; in some people the bite causes a considerable local disturbance, in others little or none.

The greater part of the body is covered with long yellow hairs, for the most part, probably, modified scales. The antennæ have sixteen joints. The proboscis is as long as the head and contains a number of piercing organs.

The wings are definitely pointed, and on removal of the outer coating of scales the venation can be seen. The insect possesses six slender legs. The abdomen is divided into ten segments.

In the *female* the abdomen is spindle-shaped, and is provided with an upper and a lower pair of small claspers. In the *male* there are five pairs of sexual appendages—the upper and lower claspers, and various other structures known as the "submedian lamellæ," "intermediate appendages," and "intromittent organ" (Newstead).

The female lays her eggs in rubble walls and in caves. The eggs, six to nine days after being laid, hatch into twelve-segmented caterpillar-like larvæ (Fig. 63), further characterized by two pairs of bristles on the posterior extremity and by the absence of eyes or organs of locomotion. In six to eight weeks the larvæ are 5 mm. in length, and feed on organic detritus and algæ. The pupæ are fixed in crevices of stones, slates, etc., the imagines emerging after fourteen days (Marett).

In the classification of these insects, entomologists have relied on the slender differences afforded by the venation of the wings, the length of segments of the palps, the number and arrangement of the bristles or spines on the claspers. Up to the present there has been little agreement on this subject. A synoptical table of the genus follows; but it should be remembered that this classification must be regarded as temporary until the group has been more extensively studied.

Great care must be exercised in the preservation of specimens for identification. The insects should be placed in a web-like layer of teased cotton-wool, but must not be *covered* with the wool, as even such slight pressure breaks their appendages.

SYNOPSIS OF THE GENUS

Asiatic and American Species

Marginal cell

Length of 2nd marginal cell ⅓ length of wing.	Head and abdomen brown; sides of thorax coxæ and trochanters yellowish; legs antennæ, and palpi grey; wings blue iridescence. *P. argentipes* (India).
Length of 2nd marginal cell more than ⅓ length of wing.	Grey, wings bluish iridescence. Greatest breadth of wing not quite ⅓ its length. *P. major* (India).
Length of 2nd marginal cell nearly ⅓ length of wing. Four spines on appendages of ♂.	Thorax, abdomen, and legs brown; wings purplish. Greatest breadth of wing ⅓ its length. *P. malabaricus* (India).
Length of 2nd marginal cell less than ⅓ length of wing.	Grey. Greatest breadth of wing between ¼ and ⅕ its length. *P. babu* (India).
Length of 2nd marginal cell more than ⅓ length of wing. Superior appendages of ♂ bear three spines.	Yellowish-grey. Greatest breadth of wing slightly over ¼ its length. *P. himalayensis* (India).
Length of 2nd marginal cell a little more than ⅓ length of wing.	Head and thorax yellowish-brown. Greatest breadth of wing ⅓ its length. *P. perturbans* (Java).
Length of 2nd marginal cell barely ⅓ length of wing.	Wings long and narrow. *P. angustipennis* (Java).
Length of 2nd marginal cell twice length of its petiole.	Yellow; mesonotum brown. *P. vexator* (N. America).
Length of 2nd marginal cell thrice length of its petiole.	Hairs chiefly yellow, otherwise like *P. vexator*. *P. cruciatus* (Guatemala).

European Species

Terminal segment of upper clasper

Terminal segment of upper clasper of ♂ slightly longer than lower segment.	Pale yellowish-grey; thorax dull red-brown with a median stripe. 2nd segment of palpi a little longer than 3rd. *P. papatasi* (Europe, Asia and Africa).
Terminal segment of upper clasper of ♂ slightly longer than lower segment.	Resembles *P. papatasii*, distinguished by darker integument and by shorter 6th longitudinal vein. *P. nigerrimus* (Europe).
Five spines of terminal segment of upper clasper very long and falciform, otherwise resembles *P. papatasii*.	. . . . . *P. mascittii* (Italy).
Terminal segment of upper clasper of ♂ half the length of the lower clasper.	Abdominal hairs more or less erect. 2nd and 3rd segments of palpi equal in length. *P. perniciosus* (Malta and Asia).
Terminal segment of upper clasper of ♂ with only four spines.	2nd segment of palpi half the length of the 3rd. Length of ♀ 2 mm. *P. minutus* (Europe, Asia, and Africa).

Additional species have lately been described—*P. rostrans* (S. America), distinguished by the large size of its head, *P. marginatus zeylanicus* (Ceylon), *P. antennatus* (Gold Coast), *P. squamipleuris* (Khartoum), *P. dubosqii* (Africa), *P. squamirentris* and *longipalpis* (Brazil). It must be distinctly understood that this list is by no means final.

CHAPTER XVI

BLACKWATER FEVER

Synonyms.—Hæmoglobinuric fever, melanuric fever, hæmaturic fever.

Definition.—An acute disease characterized by pyrexia—generally ushered in by severe rigor, bilious vomiting, icterus, hæmoglobinuria and, frequently, diminution or suppression of urine.

For a long time this disease, like kala-azar and several other tropical fevers, has been regarded as a form of malaria, and in earlier editions of this manual, in deference to general opinion, I described it, with some reservation, under that head. I have long entertained the idea that too much has been taken for granted in relegating blackwater to malaria, and thereby ignoring its possible individuality as a separate disease; an individuality strongly suggested not only by the symptomatology, but also by epidemiology and analogy. I have therefore now placed it by itself pending definite settlement of one of the most important problems still unsolved in tropical pathology. Such an arrangement, apart from other and more purely theoretical considerations, has its practical advantages.

Geographical distribution.—The geographical distribution of blackwater fever is very wide. Although it does not coincide with that of any of the known types of malaria, and although the endemicity of blackwater fever is not coextensive with that of malaria, it is only in localities in which malaria is very prevalent that blackwater fever can be acquired. Endemic concurrence, however, must not be looked on as conclusive of identity; the germ causes of very different diseases may have certain topographical requirements in common.

The prevalence of blackwater fever in various

malarious countries is most unequal. It is common here and there throughout tropical Africa. It is found all along the West Coast from the Senegal to the Coanza, but principally on the Congo and on the deltas of the Niger and Gambia rivers. On the East Coast it is also widely spread, especially along the Zambesi, the lower Shiré, and the shores of the Nyasa. It is far from uncommon in the Upper Niger, in British and German East Africa, in Uganda, in North and South Rhodesia, in Abyssinia, and in the valley of the Upper Nile. It is also common in some parts of Madagascar. But it is not found in the malarious regions of Lower Egypt, and it is rare in Algeria.

In America it extends over the Southern States of the Union, chiefly Florida, Georgia, Alabama, Mississippi, Arkansas, and Texas, but recently it has also been prevalent in North Carolina and Virginia. It is found, too, in Central America, on the plains of Venezuela and in the West Indies.

In Europe it is restricted to Greece, Sicily, and Sardinia. A few cases have been reported from Central Italy. It is extremely rare in the Roman Campagna, the classic land of malaria.

In Asia it is reported from Palestine (Zicron), Tonquin, the Malay Peninsula, and lately it has been described as occurring in Assam, Burma, Darjeeling, the Terai, Meerut, and Amritsar. It occurs in many of the malarious islands — Java, Solomon Islands, etc.—of the Eastern Archipelago, and also in New Guinea.

Before 1885, strange to say, no Indian writer had mentioned hæmoglobinuria as a feature in the pyretology of Hindustan or of the East. Apart from the possibility of its having been overlooked, there may be another explanation for this singular silence: the disease may have been confounded with bilious remittent. It is difficult to believe, however, that the large number of acute observers who had studied Indian diseases so carefully and for so many years could have systematically ignored this striking disease. Possibly, therefore, it is of recent introduction into

India. Such an idea is countenanced by the fact that certain medical men practising in Africa, good observers, declare that blackwater fever is of comparatively recent introduction there; and, moreover, that it is yearly becoming more common in that continent. In certain States of the American Union it seems to have been only recently introduced; Meek says it first appeared in Texas in 1886.

Topographical distribution. — Although blackwater fever has a wide general distribution, it is limited in its endemicity to low, swampy grounds; and although, as reported by several authors, it sometimes occurs at high altitudes, this does not prove that infection took place there. We know that the disease may remain latent for a considerable time, that those who have been infected may have relapses at long intervals, and that the clinical manifestations may appear for the first time far from the place in which the infection was contracted. It is a common belief among the older residents in British Central Africa that a change of district, particularly from one level to another, causes blackwater fever, an opinion based on the experience that many cases occur soon after such a change. Amongst Europeans in British Central Africa such changes of district are frequent, and as it is only a day's journey from the lowlands to the highlands, it is reasonable to infer that the majority of the cases which occur on the highlands depend on infection contracted previously in the swampy regions at the foot of mountains, and in the season during which the conditions favouring infection are most prevalent.

Seasonal prevalence.—In the Southern States of the American Union blackwater fever is reported to be especially frequent in late summer and in autumn. On the West Coast of Africa it seems to prevail at the close of the rainy season (August and September). For British Central Africa we have no definite information on this point. Like other infectious diseases, the acquisition of the germ cause of blackwater fever is directly or indirectly dependent on special meteorological conditions. The first clinical

manifestations of the infection and relapses may occur at any season and in any place.

Epidemiology. — Blackwater fever at times assumes an epidemic form. It may not be seen for years in a district, and then numbers of cases may occur within a short time. Very often, as is the case in yellow fever, the magnitude of an "epidemic" may depend on the number of susceptible persons, possibly new arrivals, within the endemic region. It broke out amongst the labourers employed in making the canal through the isthmus of Corinth; it attacked the Chinese labourers on the Congo railway; and in 1885, according to Dr. Wenyon, of Fatshan, China, "it ravaged like a plague the Chinese army on the Tonquin border of Kwangsi." In collective dwellings, such as barracks, hospitals, schools, it may attack several persons at the same time. In 1885 it broke out in a prison in Castiades, Sardinia, attacking 24 out of 800 convicts. Sometimes several cases may occur at long intervals in the same house; such houses are known in British Central Africa as "blackwater fever houses."*

Predisposing causes.—Individuals of all ages and both sexes are liable to blackwater fever, but they are not equally subject to it. It more commonly affects men about the middle period of life, obviously on account of their greater exposure either to its causative agent or to circumstances provocative of an attack.

At one time race was considered an important factor. In Africa, Europeans, Indians, and Chinese are attacked in great numbers, whilst the natives are said to enjoy an immunity. The immunity of the natives is probably not a racial immunity; more likely it is the immunity conferred by infection during childhood. In fact, negroes living in places

* Some years ago I saw a lady suffering from blackwater fever She with her husband and child had recently returned to England from the Upper Zambesi district. She died. I was struck with the anæmic appearance of her husband and examined his blood. He had subtertian infection. A few days after his wife's death he got blackwater fever. He was very ill but recovered. The child escaped.

which are free from blackwater fever contract the disease just like Europeans when they come within its reach. Plehn mentions a serious outbreak of blackwater fever among the blacks in the Cameroons, the disease especially attacking those who had come to the coast from the interior. Reynolds says that the disease occurs sporadically amongst the natives of Ashanti.

Among the circumstances which predispose to the active clinical manifestation of the blackwater-fever infection, debility from previous illness, bad food, or hardship have undoubtedly a powerful influence. It is usually in those who have suffered from subtertian infection, or from dysentery, or who are "run down" from any cause, that blackwater fever appears, although cases of the disease in strong, healthy individuals of recent arrival have frequently occurred.

Length of residence.—It has been repeated again and again that Europeans are rarely attacked within the first year of residence in a blackwater-fever country, and great stress has been laid on this statement by those who believe that the hæmoglobinuria is not the special feature of a specific disease, but only a symptom of ordinary malaria in people who have previously suffered from several attacks of the prevailing intermittent fever. We know, however, that although in most cases attacks of the more widely spread subtertian may precede blackwater-fever infection, yet there are many cases on record in which blackwater fever occurred before any kind of "malaria" had manifested itself. Plehn, Scott, Ritchie, Cardamatis, Lynch, Hearsey, Daniels and others have reported cases of blackwater fever in robust individuals who were attacked within two or three months of their arrival in a blackwater-fever country. I have frequently been told by officers in the African colonial service that the attack of blackwater fever for which they were invalided suddenly developed while they appeared to be in perfect health and without any malarial antecedents. Daniels states that few cases occur during the first six months' residence, that they rapidly increase during the next six

months, are most numerous during the second and third year, and become rare after five years' residence. This is exactly what might be expected to happen with any localized infectious disease. The relatively small number of cases within the first six months may be explained by non-exposure to the causative agents of the disease; indeed, many arrive in the endemic district at the end of the epidemic season. The progressive prevalence of cases during the first three years finds an obvious explanation in the accumulating chances of infection; the decrease in later years may be partly accounted for by the progressive diminution in the number of the older residents and by the weeding out of the most susceptible. Daniels states that the early cases of blackwater fever—those under one year's residence—are mainly (14 out of 21) in persons resident at or below the 1,500 feet level; and the majority (10 out of 14) of cases in persons having four years' residence are in persons residing principally in the highlands.

Etiology.—There are three theories as to the etiology of blackwater fever—1, the "malaria" theory; 2, the quinine theory; 3, the specific theory.

1. *The malaria theory.*—The prevalence of blackwater fever in malarious regions, the great frequency of its occurrence in persons who had previously suffered from one or other of the malarial fevers, the finding of malaria parasites and hæmozoin in the blood and organs, and the large mononuclear leucocytosis of hæmoglobinuric cases led to the belief that blackwater fever was an unusually severe form of "malaria." Against this theory is the fact that although blackwater fever is certainly co-endemic with one or other form of malaria in several regions, it is not so in all regions. It has its own peculiar distribution, and is absent or very rare in many places in which the various intermittent fevers are especially rife. It is exceedingly common amongst the few Europeans who live in tropical Africa; it is practically unknown amongst the many thousands of Englishmen who live in the fever haunts of India and elsewhere.

It is quite true that blackwater fever generally occurs in persons who have previously suffered or are suffering from malaria; but this does not prove that it is a special manifestation of malaria. It may be concurrence merely. We do not believe tuberculosis to be a peculiar manifestation of enteric fever because it often follows in the wake of that disease. Moreover, as already pointed out, blackwater fever frequently attacks people who previously had never had a single paroxysm of intermittent fever. The fact that malaria parasites are often found in the early stages of blackwater fever is not surprising when we consider that in many places malaria is exceedingly common and is co-endemic with blackwater fever. Although the tertian and quartan parasites have been found in the blood of blackwater fever cases, the parasite which most frequently occurs is the subtertian, because it is that species of malaria parasite which is most common in the endemic regions of blackwater fever. Yet of all the intermittent fevers, subtertian is the one that differs most, clinically, from blackwater fever. It is true that subtertian varies considerably in different cases; but the type of the disease does not alter, and the number and distribution of the parasites in the organs are always in perfect accordance with the intensity and nature of the various symptoms. In no case of subtertian, not even in the most pernicious, do we ever find the symptoms peculiar to blackwater fever. On the other hand, all cases of blackwater fever, however grave, however mild, always exhibit the same characteristic symptoms, with no difference other than as regards intensity and duration. Admitting the malaria theory of blackwater fever, we should have to consider a mild relapse of blackwater fever to be an unusually severe attack of subtertian; an untenable paradox. When malaria parasites are found in cases of blackwater fever they may be very scanty and in no way proportional to the symptoms of the disease. But in many cases no parasites are found; or, what is still more striking, if there were a few parasites before the attack, they invariably completely disappear with the onset of

blackwater fever, and may not return after recovery from the latter disease. In analogy with what is sometimes observed in pernicious cases of subtertian fever, some authors have suggested that the parasites, though scarce or even absent in the peripheral blood, may be numerous in some internal organ, particularly the brain. Against this a priori argument are the absence of cerebral symptoms during the attack, and the occasional negative evidence of post-mortem findings.

Much has been made of the large mononuclear leucocytosis present in this disease as a proof of its malarial nature. But we now know that a similar type of leucocytosis occurs in several other forms of protozoal disease.

If blackwater fever be caused by any one of the known malaria parasites, this parasite must have acquired its peculiarly powerful hæmolytic properties in a previous passage through an as yet unrecognized mammalian or insect host; or the subject of blackwater fever must have been exposed to some specific influence present in blackwater fever countries, but absent in other malarial districts.

2. *The quinine theory.*—The quinine theory of blackwater fever arose in Greece. It was first suggested by Verétas in 1858, and soon became popular amongst Greek physicians. In 1874 it was upheld by Tomaselli in Italy, and more recently it received the support of Koch. The idea that quinine might produce blackwater fever originated from a misinterpretation of the fact that the administration of quinine, even in small doses, may provoke the manifestation of blackwater fever in a patient in whom the infection is latent. As quinine, even in toxic doses, never produces blackwater fever in healthy people or in malaria patients elsewhere, its peculiar action in Africa had to be explained by a peculiar hypothetical idiosyncrasy—an idiosyncrasy which, curiously enough, is found only in certain malarious countries and not in others. Thus, the connection between quinine and blackwater fever is not one of cause and effect, but merely one of coincidence. Blackwater

fever was known long before the introduction of cinchona bark into Europe, indeed it was known in the days of Hippocrates. Besides, even recently, numerous cases of blackwater fever have been reported amongst Europeans who had never taken quinine. Cardamatis mentions thirty-two such cases. Then, again, a number of physicians have administered quinine in large doses for the treatment of blackwater fever and have greatly vaunted its beneficial action. Quinine, undoubtedly, provokes in some the clinical manifestation of blackwater-fever infection. So, and probably much more powerfully, do chill and fatigue. But no one will contend that the latter cause the disease. Why then attribute it to quinine, which, logically, has no stronger claim?

3. *The specific theory.*—In 1893, in a paper read before the Epidemiological Society, I stated that, on account of its peculiar symptoms and geographical distribution, I believed blackwater to be a disease *sui generis*. In 1898, Sambon suggested, because of the striking analogies that its distribution, course, symptoms and morbid appearances have with the hæmoglobinuric fevers of cattle, horses, dogs and sheep, that blackwater fever might be a form of babesiasis. This view, which has been adopted quite recently by Blanchard and others, deserves consideration. It is quite reasonable to expect to find in man parasites belonging to this genus of the hæmoprotozoa, so abundantly represented amongst the animals most intimately associated with him. Certainly, of all the diseases of man of which the etiology is still obscure, none could be more appropriately ascribed to this group of parasites. The analogies between the hæmoglobinuric fever of man and the hæmoglobinuric fevers of cattle are most striking. To explain the fact that as yet no babesia has been found in cases of blackwater fever, I might suggest that either the amœboid forms of the parasite have been mistaken for the early forms of the subtertian parasite, or that the parasite has escaped observation on account of diminutive size or ana-

tomical habitat, or because it is not usually found in the peripheral blood.*

Edington claims to have shown that when cattle, natives of the South African endemic regions of Texas fever, are inoculated with rinderpest, they develop hæmoglobinuria and the other symptoms of Texas fever, from which disease they might be supposed to be pathologically immune. The blood of immune cattle in Texas fever regions, we know, contains, in small numbers, the babesia. Edington's experiments show that the supervention of a second infection, rinderpest, determines the multiplication of the latent babesia, and the explosion of the characteristic symptoms. May this not be in strict analogy with what happens in blackwater fever? The infection of blackwater fever may remain latent for considerable periods, until provoked into activity by some special agency, as cold, shock, quinine, or some additional infection, e.g. malaria.

Manifestly, the etiology of blackwater fever is not yet settled, and it is wise to preserve an open mind on this important subject.

Incubation period. — We know nothing definite as to the incubation period of blackwater fever. Scott, in British Central Africa, noticed that the attack usually occurred about eight days after exposure in certain low-lying districts. That the disease may remain in abeyance for a considerable time is proved by the facts that recurrences after long intervals—months—are very common, in fact the rule; and that in some cases the first attack may manifest itself in Europe several months after the patient has left the endemic regions. I have recently met with a case in England in which a severe attack, followed by a still more severe and prolonged relapse, was the first manifestation of a blackwater-fever

* Leishman has recently described certain minute and somewhat ill-defined bodies in mononuclear corpuscles in the blood of a number of cases of blackwater fever. He does not claim that these bodies are parasites, but he does not deny that they may be of that nature. He also describes peculiar cells; he calls them "chrome cells" in the blood of such cases. Balfour has found similar cells in blackwater. Low, Wenyon, and Schilling Torgau have found similar bodies in other diseases.

infection which must have been acquired at least nine and a half months previously—the time that had elapsed since the patient left Africa.

Symptoms.—The onset of blackwater fever is usually sudden. A slight or, more generally, a very severe rigor is followed by intermitting, or remitting, or irregular fever with marked bilious symptoms. Earlier or later in the attack, usually during rigor, the patient becomes conscious of aching, perhaps severe, pain in the loins, in the region of the liver and spleen, and over the bladder; in exceptional instances these local pains are absent. In consequence of a somewhat urgent desire he passes water, when he is astonished to see that his urine has become very dark in colour, perhaps malaga-coloured or, possibly, almost black. The fever continues, though not necessarily very high. Very likely he suffers from epigastric pain and distress, bilious vomiting to an unusual extent, and, it may be, bilious diarrhœa; or he may be constipated. The pain in the loins and the liver-ache continue, and the urine becomes darker and darker. By and by the sufferer breaks into a profuse sweat and the fever gradually subsides. The urine, which hitherto may have been very abundant, or, perhaps, somewhat scanty, now flows freely; and, after passing through various paling shades, from dark brown to sherry red, becomes once more natural in appearance. Coincidently with the appearance of the dark colour in the urine, or even before this has been remarked, the skin and scleræ rapidly acquire a deep saffron-yellow tint. This icteric condition persists and even deepens during the progress of the fever, continuing for several days to be a striking feature in the symptoms. When the fever subsides the patient is conscious of a feeling of intense weakness from which he recovers but slowly. Fever, with or without rigor, may recur next day, or for several days; or it may cease; or it may be remittent, or almost continued in type. The hæmoglobinuria may recur with each rise of temperature; or there may be only one or two outbursts; it may continue for an hour or two only;

or it may persist off and on for several days or even weeks.

In the more severe forms of hæmoglobinuric fever there is usually a very great amount of bilious vomiting, of intense epigastric distress, and of severe liver- and loin-ache. The urine may continue copious and very dark in colour; or, continuing hæmoglobinous, it may gradually get more and more scanty, acquiring a gummy consistence, a few drops only being passed at a time. Finally, it may be completely suppressed.

In severe cases death is the rule. It appears to be brought about in one of three or four ways. The fever may assume the typho-adynamic type; or suddenly-developed cerebral, hyperpyrexial or algide symptoms may supervene. In other cases the symptoms may be like those consequent on sudden and profuse hæmorrhage—jactitation, sweating, sighing, syncope. Or it may be that suppression of urine, persisting for several days, terminates, as cases of suppression usually do, in sudden syncope or convulsions and coma. Or, more rarely, nephritis may ensue and the patient die from uræmic trouble three or four weeks after all signs of hæmoglobinuria and fever have disappeared.

Recently I saw in London a case in which the fatal issue appeared to have been brought about by persistent hiccough—always a bad sign—hepatitis, and vomiting of blood.

The urine.—If the characteristic dark-brown, generally acid, urine of a hæmoglobinuric case be stood for some time in a urine glass, it will separate into two well-marked layers: an upper of a clear though very dark port-wine tint, and a lower—perhaps amounting to one-half or one-third of the entire bulk—of a somewhat brownish-grey colour, and consisting of a sediment in which an enormous number of hyaline and hæmoglobin tube casts are to be found, together with a large quantity of brownish granular material. Epithelium is also met with. Blood corpuscles may be entirely absent, or very few in number. With the hæmoglobin there is also an escape of the serum-globulin of the blood,

for the urine, in many cases, turns almost solid on boiling; the coagulum so formed carries down with it as it subsides the dissolved and suspended hæmoglobin, leaving a pale-yellow supernatant urine. For some days after the urine has regained a normal appearance it will still contain albumin, though in gradually diminishing amount. Spectroscopic examination gives the characteristic bands of hæmoglobin, sometimes those of methæmoglobin.

Mortality.—This varies greatly in different epidemics, in the same and in different places, and even under the same treatment. Some cases are so mild and transient, amounting, perhaps, to a single emission of hæmoglobinous urine, with little or no fever, that they are unattended with risk; on the other hand, a practitioner may encounter a run of severe cases in which nearly all die. Some old residents in Africa have passed through ten or more attacks with impunity. Taking one with the other, the case mortality in blackwater fever may be put down at about 25 per cent.

Post-mortem appearances. *The kidneys.*—If the kidneys of a fatal case are examined at an early stage of the disease, they are seen to be enlarged and congested, the tubules blocked with hæmoglobin infarcts, the cells laden with yellow pigment grains, and the capillaries most probably with a certain amount of malarial pigment. If the case survive for three or four weeks and then die of uræmia, the appearances are those of large white kidney.

The spleen is enlarged, congested, and usually contains malarial pigment.

The liver is enlarged, soft, of a dark-yellow colour. Microscopically it reveals evidence of cloudy swelling with a large amount of hæmosiderin in the liver cells. Hæmozoin may or may not be present.

Diagnosis.—The diseases with which blackwater fever might be confounded are — 1, paroxysmal hæmoglobinuria; 2, bilious remittent malaria; 3, yellow fever; 4, icterus gravis. If it be borne in mind that rigor, hæmoglobinuria, pyrexia, are all

in evidence at the outset in blackwater fever, and also that blackwater fever is acquired only in certain countries, an error in diagnosis is improbable.

As regards paroxysmal hæmoglobinuria occurring in the tropics, a diagnosis might be impossible. Both diseases have the same symptoms. Paroxysmal hæmoglobinuria, as a rule, is of a milder type. In bilious remittent malaria an examination of the urine will suffice to exclude one of the characteristics of blackwater fever, namely, the presence of hæmoglobin. Moreover, the malaria parasite will be present in the blood throughout the fever until quinine has been administered. In yellow fever the initial rigor is rarely severe, the appearance of icterus is a comparatively late event, the spleen and liver are not usually enlarged, the urine is albuminous, and if blood be present the erythrocytes are abundant. The same remarks apply to icterus gravis.

Treatment.—Having regard to the frequency with which hæmoglobinuric fever concurs with malarial infection, and the well-established fact that quinine may precipitate or determine a hæmoglobinuric attack, the question of the administration of that drug in hæmoglobinuria becomes an important point. Some practitioners of experience recommend the exhibition of the drug in heroic doses, giving it every two hours in divided doses to the extent of 120 gr. a day; this they keep up till convalescence is established. On the other hand, hæmoglobinuria may come on while the patient is cinchonized. The Plehns, Koch, and others, after trying quinine in these cases, and carefully comparing the results of treatment both with and without quinine, abandoned its use. So long as the hæmoglobinuria continued they treated the case symptomatically, cautiously resuming the specific if the case merged into and concluded as a simple intermittent. There can be no doubt that in large doses quinine exercises a certain amount of destructive action on the blood corpuscles, rendering their hæmoglobin unstable. When, therefore, its toxic influence is superadded to that of the specific cause of the hæmoglobinuric fever, it may be that it supplies

the little that is required to determine an extensive liberation of hæmoglobin, which, had the quinine been withheld, might not have taken place. Bastianelli lays down the following sensible rules as to the use of quinine in hæmoglobinuric fever: (*a*) If hæmoglobinuria occurs during a malarial paroxysm and parasites are found in the blood, quinine should be given. (*b*) If parasites are not found in the blood, quinine should not be given. (*c*) If quinine has been already given before the hæmoglobinuria has appeared, and no parasites are found, its use should be suspended; but if parasites persist it should be continued.

Recommendations.—Patients who are suffering from or are threatened with hæmoglobinuria, or who have had this disease before, on the slightest indication of fever should go to bed at once, keep their skins warm and scrupulously protected from draughts, and take plenty of warm fluid; if parasites are present in the blood, moderate doses—5 gr.—of quinine every three or four hours (intramuscularly by preference) and a moderate dose of calomel should be given.

When the urine tends to be suppressed, diuretics must not be given with the idea of stimulating the kidneys. In these circumstances hot fomentations should be applied to the loins, plenty of bland diluents administered, and an exclusive milk diet ordered until all albumin has disappeared from the urine. Indeed, even in the mildest as well as the gravest cases, the free and frequent administration of fluid is a most important measure, whether the patient is thirsty or not, and should be insisted on from the beginning of the attack. When, owing to persistent vomiting, fluid cannot be retained by the stomach, enemata of warm physiological salt solution (much less irritating to the bowel, and thus far more likely to be retained than plain water) should be administered repeatedly, 6–8 oz. every half-hour or hour. If these are not retained, the salt solution (a teaspoonful to the pint of sterilized water), sterilized, may be slowly introduced into the subcutaneous connective tissue of the flank or elsewhere by means of a hollow needle attached by a rubber tube to some improvised reser-

voir placed one or two feet above the level of the patient. The water is rapidly absorbed, and cannot fail to be useful in washing out the hæmoglobin infarcts which plug the renal tubules and bring about, or at all events contribute to, suppression of urine. Marked restlessness may require minute doses of morphia ($\frac{1}{10}$ gr.); but this drug, of great use at times, must be employed with caution. This is the only rational and safe systematic treatment of hæmoglobinuric fever. Antipyretic drugs, as antipyrin and phenacetin, are dangerous.

Sternberg's mixture of bichloride of mercury and sodium bicarbonate (p. 263) has come into favour lately, especially in Central Africa.

Calomel in large doses — 20 to 30 gr. — is with some a favourite remedy for hæmoglobinuric fever. Formerly it was used systematically in Africa in these cases. I have heard of its being given there by the teaspoonful. I know of cases which recovered perfectly without a grain of calomel or of quinine. Severe stomatitis may arise from the former; it should therefore be employed with great caution, and in reasonable dose.

Quennec has advocated the administration of small doses of *chloroform* in hæmoglobinuric fever. His formula is chloroform 4 grm., powdered gum q.s., sweetened water 250 c.c.: of this a tablespoonful is given every ten minutes until a certain degree of chloroform intoxication is produced. Thereafter the effect is kept up by enemata of chloral. In twenty-two successive cases Quennec had no death.

Tannic acid is another drug which enjoys a certain reputation in the treatment of malarial fevers that have resisted quinine, and also in hæmoglobinuric fever. It is given, well diluted, in 15-gr. doses every two hours for four or five times, the dosing being repeated on the third and sixth days to the extent of two doses each day.

Salicylate of soda, boric acid, chloride of calcium, potash, preparations of Beereana, are used by some medical men in West Africa at the present time, and, it is said, as of many other drugs, with good results.

Transfusion of blood has been successfully practised in high degrees of anæmia in some cases. *Oxygen* inhalations are indicated, but are rarely available.

In desperate cases of suppression of urine, Stannus suggests, and has practised with temporary success in one case, incision of the kidney; Sorel has employed intravenous injection of isotonic solution of sugar in six cases with success.

Nursing is a most important element in the management of blackwater fever. If the stomach will retain food this should be given in a bland and fluid form, but there should be no attempt to force feeding, especially with rich and indigestible viands. One precaution against syncope must be sedulously enforced: the patient must not be allowed to sit up, much less to get out of bed, until food has been retained and assimilated, and the risk of sudden death from syncope has passed.

If possible, the subject of a hæmoglobinuric attack should quit the endemic area, and never return to it, or to any malarial locality; a severe attack, or a second attack, implying as they would special liability, should be regarded as imperative indications to this effect.

Prophylaxis.—All depressing and predisposing causes must be carefully avoided, more especially chill, fatigue, and malaria, and also irregular dosing with quinine. In blackwater regions those who are the subjects of malarial infection should take quinine systematically, never irregularly, and should be especially careful to continue its use, in the accustomed doses and at the accustomed intervals, for at least six months after arrival in Europe. Most of the cases of blackwater I have seen in this country were, I believe, attributable to neglect of this precaution and to a big dose of quinine taken for a relapse of a malarial infection supposed to have died out. Those who have had blackwater should gradually habituate themselves to quinine, beginning with minute doses—$\frac{1}{5}$ gr.—slowly increased to 5 gr., which dose they should take daily while under the endemic influences, and at least for six months afterwards.

CHAPTER XVII

SPOTTED FEVER OF THE ROCKY MOUNTAINS

Definition.—A specific fever resembling symptomatically typhus exanthematicus, supervening on the bite of a tick—*Dermacentor venustus*, Banks.

History.—For upwards of thirty years a peculiar disease variously named "spotted fever," "blue disease," "black fever," has been recognized as endemic in limited districts of Montana and Idaho, United States of America. It was first described by Maxey, in 1899, as a distinct disease, and in the spring of 1902 it was investigated by Wilson and Chowning, who attributed it to the presence in the blood of a parasite akin to the babesia of Texas cattle fever. Their results were endorsed by Wesbrook, Cobb and Anderson; but in May, 1904, Wardell Stiles failed to recognize the parasite, either in fresh preparations of the blood or in the preparations of previous investigators. Other observers have been equally unsuccessful; the existence of the so-called *Pyrosoma hominis* is now discredited, and the germ of Rocky Mountain fever is still unknown.

In 1906 King definitely ascertained that the disease supervened on the bite of a certain tick, *Dermacentor venustus* (*D. andersoni*) (Figs. 64, 65), a discovery subsequently confirmed by Ricketts, who succeeded in conveying the infection to a monkey by means of an infected tick. McClintick in 1911, in researches conducted at the instance of the United States Government, failed to communicate the disease to guineapigs, but unfortunately himself contracted the infection and died.

Geographical distribution.—The disease has been reported for several of the Western States of the American Union—Idaho, Montana, Wyoming, Utah, Nevada, Oregon, and Washington State. It is

believed to occur also in the Alaska territory. It is found principally in valleys and near the foot-hills of mountains in sharply-defined and limited areas, and is confined to the spring months, the greatest number of cases occurring between March and July. It attacks any age, either sex, and is not directly contagious.

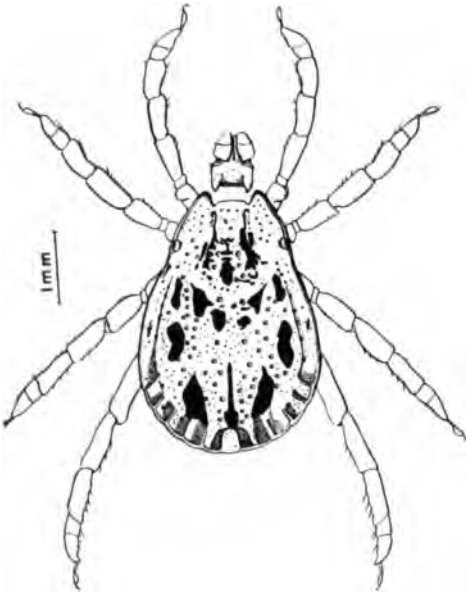


Fig. 64.—Dermacentor venustus, ♂. (*By courtesy of Prof. Nuttall.*)

Symptoms.—A short period of malaise is followed by chills, which are repeated with diminishing severity at irregular intervals throughout the attack. By the second day the temperature has risen to 103° or 104° F., and by the fifth day to 105° or 107°. A typhoid-like condition, with low muttering delirium and semi-consciousness, is rapidly developed. If the patient is to recover, the temperature begins to fall about the end of the second week, fever subsiding usually by lysis.

About from the fourth to the seventh day an eruption appears on the wrists, ankles, or back, extending rapidly to the trunk, scalp, hands, and feet. At first it consists of minute rose-coloured spots; these soon assume a petechial character and, spreading, tend to become confluent, especially on the more dependent parts of the body and limbs. In other instances the spots remain discrete, brownish or

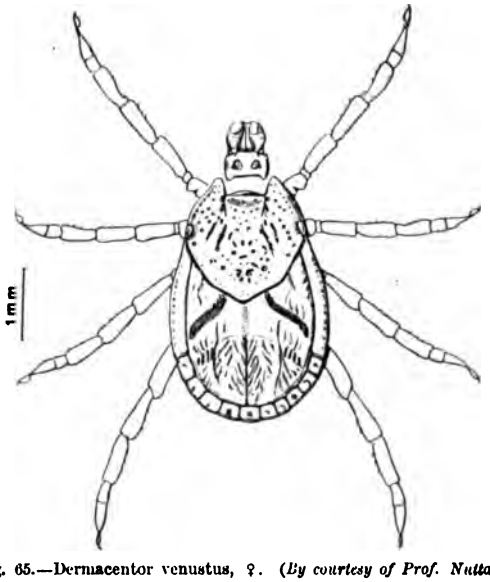


Fig. 65.—Dermacentor venustus, ♀. (*By courtesy of Prof. Nuttall.*)

purplish in colour, giving to the surface of the body a speckled appearance. A certain amount of icteric tinting of skin and scleræ is also present. During the third week desquamation sets in, the eruption fading as fever subsides. In some cases the skin of the elbows, fingers, toes, lobes of the ears, etc., becomes gangrenous.

Constipation is usual. The liver is slightly enlarged, the spleen markedly enlarged and tender. The scanty, high-coloured urine may contain albumin

and casts. Early, in all severe cases, there is œdema of the face and limbs. Nausea and vomiting set in about the beginning of the second week, and persist in fatal cases. Respiration is rapid. A slight catarrhal condition of the respiratory tract is present throughout; the pulse loses in volume as it increases in frequency. There appears to be but slight diminution in the blood count, and only a feeble leucocytosis—12,000 to 13,000; the hæmoglobin is slightly diminished.

Pathology.—Post-mortem, in addition to the foregoing skin lesions, there is marked hypostatic congestion of the lungs, subserous petechiæ, softened myocardium, enlarged and softened spleen, fatty degeneration of the hepatic cells, and congestion of the cortex of the kidneys.

Etiology.—The evidence is now conclusive that the germ of Rocky Mountain fever is introduced by the bites of *D. venustus*.* It is only the adult that attacks man. The Rocky Mountain goat and the domestic sheep also serve as hosts to the adult forms, but the larval and nymph stages develop principally on the ground squirrel, *Citellus columbianus*, and the woodchuck, *Marmota flaviventer*. The tick takes two years to develop, hibernating during the winter, feeding but languidly after the beginning of August, and reviving during the first warm days in April. It is possible that the Rocky Mountain goat serves as a natural reservoir of the disease virus.

According to Ricketts, the unrecognized germ is intimately attached to the blood corpuscles, is easily inoculated into man, and can be passed through an indefinite series of monkeys and guineapigs, giving rise in them to the characteristic symptoms and producing immunity. The larva, nymph, and adult male and female tick are all of them efficient intermediaries. Ricketts suggests, seeing that in one place—Montana—the case mortality in man is as high as 90 per cent.,

* *D. venustus* and *D. andersoni* are the same species. The differences in the nomenclature of the tick used by various authors have resulted in a good deal of confusion. *D. reticulatus* and *D. occidentalis*, apparently distinct species, have at various times been incriminated as carriers of the infection.

whereas in another place—Idaho—it is only 5 per cent., that there are two species of tick, in the former *D. venustus*, in the latter *D. maturatus*, capable of transmitting the infection. The proportion of infected ticks in natural conditions is small; only 1 in 296 in Ricketts' experience.

In conformity with the seasonal prevalence of the tick, the disease in man is commonest in April, May, and June, although cases are met with throughout the year.*

Treatment and prophylaxis.—In the absence of a specific remedy, treatment must be conducted on general principles, having regard to the natural history and nature of the disease. Attempts at prophylaxis are now being carried out, based on the above-described hypothetical method of transmission of the disease. War is being waged on the ground squirrel and the woodchuck; domestic stock and goats are being systematically dipped to prevent the spread of and, if possible, to exterminate the tick.

* **Tick paralysis.**—According to Hadwen, the tick, *D. venustus*, as it occurs in the dry district of British Columbia, Keremeos, gives rise to a peculiar form of paraplegia in sheep which, directly or indirectly, may prove fatal. In the same district it affects man and other animals in a similar way. Todd has called attention to this disease, of which he has collected a considerable number of cases, some of them fatal. Nuttall, working in Cambridge, England, has confirmed Hadwen's experiments. He placed one of the ticks received from Hadwen on a healthy dog. Twelve days afterwards the dog became completely paralysed in fore- and hind-legs. Ultimately it gradually recovered.

This form of tick disease is manifestly different from Rocky Mountain fever, as it is non-febrile, is unattended with eruption, and is not communicable by inoculation. Possibly it is produced by a poison instilled by the tick during haustellation. The wound it makes is very painful, is attended with œdema and, on forcible removal of the tick, with free bleeding as if some anticoagulin had been introduced.

In sheep the favourite points of attachment of the tick are on the back along the course of the spine; in man, the nape of the neck.

A somewhat similar form of paralysis is described by Eaton as following on tick bite in Queensland, Australia, the incriminated tick being *Ixodes ricinus*. Bancroft reports from the same country a similarly caused form of epileptiform convulsions in cats and dogs.

CHAPTER XVIII

JAPANESE RIVER FEVER (SHIMA MUSHI)

Definition.—An acute endemic disease running a definite course and attended with a considerable mortality. It is characterized by the presence on the skin of an initial eschar, supervening on the bite of a species of Trombidium. This is followed by an ulcer, lymphatitis, fever, an exanthematous eruption, bronchitis, and conjunctivitis.

History.—This disease was first described by Palm in 1878, and subsequently, and more fully, by Baelz and Kawakami.

Geographical and seasonal distribution.—So far as known, shima mushi is confined to the banks of two rivers on the west side of the island of Nippon—the Shinanogawa and one of its tributaries, and the Omonagawa. Every spring these rivers inundate large tracts of country. Later in the year hemp is raised on strips of the inundated district. The crop is reaped in July and August, and it is solely among those engaged in harvesting and handling this that the disease occurs. It is not communicable by the sick to the healthy. Although transportable in the hemp to a very slight extent, it is only in limited spots here and there in the endemic districts that the virus originates.

Etiology.—The Japanese attribute this disease to the bite of a larval acarus (locally called *aka mushi*—red insect) resembling the *Leptus autumnalis* of Europe. Baelz rejects this idea, but does not explain how otherwise the virus is introduced. Men, women, and children are equally susceptible. New arrivals in infected districts are said to be more liable to contract the disease. One attack does not confer immunity, although it may render subsequent attacks

less severe. As yet the virus of the disease, which doubtless enters in the first instance at the site of the primary eschar, has not been discovered. Mizayima states that shima mushi is communicable to the monkey by the bite of the insect, and, also, by inoculation from a human patient.

Symptoms.—After an incubation period of from four to seven days the disease usually begins with malaise, frontal and temporal headache, anorexia, chills alternating with flushes of heat, and prostration. Presently the patient becomes conscious of pain and tenderness in the lymphatic glands of the groin, armpit, or neck. On inspecting the skin of the corresponding lymphatic area there is discovered—usually about the genitals or armpits—a small (2 to 4 mm.), round, dark, tough, firmly adherent eschar surrounded by a painless livid red areola of superficial congestion. Occasionally two or three such eschars are discovered. Although a line of tenderness may be traced from the sore to the swollen, hard, and sensitive glands, no well-defined cord of lymphatitis can be made out. The superficial lymphatic glands of the rest of the body, especially those on the opposite side corresponding to the glands primarily affected, are also, but more slightly, enlarged.

Fever of a more or less continued type now sets in, the thermometer mounting in the course of five or six days to 40° or 41° C. The conjunctivæ become injected, and the eyes somewhat prominent; at the same time a considerable bronchitis gives rise to harassing cough. The pulse is full and strong, ranging rather low—80 to 100—for the degree of fever present. The spleen is moderately but distinctly enlarged, and there is marked constipation.

About the sixth or seventh day an eruption of large dark-red papules appears on the face, tending to become confluent on the cheeks. It then extends to the forearms, legs, and trunk, being less pronounced on the upper arms, thighs, neck, and palate. Simultaneously with the papules a minute lichenous eruption breaks out on the forearms and trunk. This lasts usually from four to seven days; if but

slightly marked the eruption may fade in twenty-four hours.

The patients during the height of the fever are flushed, and at night, it may be, delirious. They complain incessantly, probably on account of a general hyperæsthesia of skin and muscles. Deafness is also a feature.

As the disease advances, the symptoms become more urgent; the conjunctivitis is intensified, the cough becomes incessant, the tongue dries, the lips crack and bleed, and there may be from time to time profuse perspiration. By the end of the second week—sooner or later according to the severity of the case—the fever begins to remit, the tongue to clean, and, after a few days, temperature falls to normal, and the patient speedily convalesces. Ashburn and Craig have noted a well-marked leucopenia. The red cells are normal. Diarrhœa or diuresis may occur during the decline of the fever. The circular, sharp-edged, deep ulcer left after the separation of the primary eschar—an event which usually takes place during the second week—now begins to heal, and the enlargement of the glands gradually to subside.

Such is the course of a moderately severe case. In some instances, however, the constitutional disturbance is very slight, although the primary eschar may be well marked and perhaps extensive. On the other hand, the fever may be much more violent, and complications such as parotitis, melæna, coma, mania, cardiac failure, or œdema of the lungs may end in death. Similarly, the duration of the disease varies according to severity from one to four weeks, three weeks being about the average.

Pregnant women contracting shima mushi mostly abort and die.

The **mortality** in those attacked is approximately about 27 per cent.

Pathological anatomy. — Beyond evidences of bronchial catarrh, hypostatic pneumonia, enlarged spleen, perisplenitis, patchy reddening of the intestine near the ileo-cæcal valve, injection of the peritoneum,

and slight enlargement of the mesenteric and superficial lymphatic glands, no noteworthy lesions have been described.

Treatment.—On the supposition that the disease is introduced by an insect, or through a wound of some sort, care should be exercised by those engaged in hemp culture in the endemic district to protect and keep clean the skin, especially that about the genitals and armpits. There is no specific remedy for the disease; treatment must therefore be conducted on general principles.

CHAPTER XIX

PLAGUE

Definition.—Plague is a specific, inoculable, and otherwise communicable epidemic disease common to man and many of the lower animals. It is characterized by fever, adenitis, a rapid course, a very high mortality, and the presence of a specific bacterium, *Bacillus pestis*, in the lymphatic glands, viscera, and blood. In a large proportion of cases buboes form in the groins, armpits, or neck.

Geographical distribution. — Though not necessarily confined to warm climates, in modern times plague, like leprosy, has practically become so. The hygienic conditions which advancing civilization has brought in its train have forced back these two diseases from Europe, where at one time they were even more prevalent than they are in their present tropical and sub-tropical haunts. Plague and leprosy are typical examples of that large group of acute and chronic germ diseases whose spread depends on social and hygienic rather than on climatic conditions, and more especially on the verminous accompaniments of filth and overcrowding: conditions which nowadays are found, to an extent and an intensity sufficient to ensure the endemic prevalence or epidemic extension of these diseases, for the most part only in warm countries.

It is difficult to say what the *pestis* of the ancients may have been. Probably in many instances it was bubonic plague; doubtless the term was sometimes applied to other epidemic sicknesses attended with a large mortality.

The descriptions which have come down to us of these old-world epidemics are too vague for recognition. According to Hirsch, the first recognizable description of what is now understood by plague

refers to its occurrence in Libya, Egypt, and Syria about the end of the third and the beginning of the second century before the Christian era. The next authentic account, and the first as regards Europe, refers to the great epidemic known as the plague of Justinian, which, in A.D. 542, starting from Egypt, spread to Europe and all over the Roman Empire, and which, lasting for fifty or sixty years, wrought the most frightful devastation wherever it reached, depopulating the towns and turning the country into a desert. From that time until 1841, when plague appeared for the last time in Constantinople, it recurred again and again in different parts of Europe, though latterly only in the south-eastern parts of the continent and in areas becoming gradually more circumscribed. In 1878-79 a small epidemic, which speedily died out, broke out in the Russian province of Astrakhan. With the latter exception and the limited epidemics at Oporto in 1899 and at Glasgow in 1901, and a few isolated and mostly imported cases at the large seaports, Europe has long enjoyed exemption from this worst of epidemic diseases. The plague, as a widespread epidemic, visited England for the last time in 1664-79, when, in 1664-65, upwards of 70,000 of the 460,000 inhabitants of the London of that day perished. In recent years and from time to time cases of plague have occurred in the Port of London in seamen from Eastern countries, and plague-infected rats are by no means uncommon in the docks of the metropolis, but with the exception of a limited epizootic in rats and rabbits and several fatal cases in man in 1910 in Norfolk there is no record of plague in England, apart from the cases occasionally seen in the seaports, since the seventeenth century.

Egypt, in former times a favourite haunt of the disease, until 1899 had been exempt since 1844, although several epidemics have since the latter date occurred in its neighbourhood—in Tripoli (Benghasi) in 1856, in 1859, and in 1874; and on the Red Sea coast of Arabia (Assir) from 1853 to the present time. It is now known to be endemic in Uganda and in the hinterland of German East Africa.

Many epidemics have occurred in Mesopotamia (last in 1892), in Turkestan (last in 1892), in India, in China, and in Mongolia. In India there were several outbreaks during the nineteenth century, but, with the exception of the current epidemic, they were of a localized rather than of a general character. One, beginning in Cutch in 1815, spread to Scinde and Gujerat, and continued till 1821. Epidemics have also occurred in Kumaon and Gharval on the southern slopes of the Himalayas in 1824, 1834–37, 1846–53, 1876, and 1884; also at Hansi in Delhi, 1828–29. In 1836 it appeared at Bareilly, Rohilcund, and at Pali in Rajputana, spreading to Jodhpore and to Marwar, and continuing till 1838. Probably plague is always present in some part of India, especially among the rude hill-peoples.

It is now known that plague has been endemic in the south-west of China, in the province of Yunnan, for many years. It is probable that the present extension of plague had its origin in that part of China. There it was seen by Rocher and others in 1878 and afterwards. It was particularly active in 1871–73, after the great Mohammedan rebellion. From Yunnan, probably following the trade route, it spread to Pakhoi on the Gulf of Tonquin, a severe epidemic occurring in 1883 in that and in neighbouring towns. In 1894 it had extended to Canton, where it killed, it is estimated, 60,000 in a population of 1,500,000 (?). Later in the spring of the same year it broke out in the British colony of Hong Kong, subsequently spreading to Macao, Swatow, Amoy, Foochow, Formosa, and probably to many other places in the southern provinces of the Chinese Empire, where, in one place after another, considering the wretched hygienic conditions and the poverty of the inhabitants, it is safe to prophesy that plague will continue epidemic for many years to come. Japan and the Philippines were both infected from China.

Having probably been imported from Hong Kong, it appeared in 1896 at Bombay, and subsequently as

a great epidemic spread to Calcutta, and to many other parts of India, where it still prevails. Indian official returns give the total plague mortality from the current epidemic up to December, 1905, as 4,097,764. In 1911 there were 842,000 and in 1912 273,000 deaths.

Soon after its appearance in India, plague became extensively epidemic in Mauritius, where it still prevails at certain seasons. Madagascar, Delagoa Bay, Cape Town, Port Elizabeth in Cape Colony, and Durban; also Sydney and Brisbane in Australia, and Alexandria in Egypt, have all been invaded.

Until its recent appearance in Brazil, the Argentine and other South American countries, in San Francisco and Mexico, plague had never invaded the western hemisphere.

Etiology. *The micro-organism.*—The proofs are now complete that the specific cause of plague is the cocco-bacillus which was discovered first by Kitasato and afterwards, independently, by Yersin during the Hong Kong epidemic in 1894. This microbe occurs in great profusion in the characteristic buboes —generally in pure culture, although towards the later stages it is often associated with the streptococci and staphylococci of suppuration. It is present, besides, in great abundance, in the spleen, intestines, lungs, kidneys, liver, and other viscera, and also, though in smaller numbers, in the blood. In the pneumonic type of the disease it is present in the sputum in enormous numbers. It occurs also in the urine and fæces; in the latter, though detectable by inoculation and by cultivation, the bacillus may be hard to find by direct observation. Towards the termination of rapidly fatal cases it may become so abundant in the blood as to be readily observed there with the microscope.

The plague bacterium (Fig. 66), as seen in smearings or scrapings from the pulp of the buboes, or from any of the inflamed lymphatic glands, or from the viscera, is a short, thick cocco-bacillus (1·5 to 2 μ and 0·5 to 0·7 μ) with rounded ends, very like that of chicken cholera. Gordon says it has

terminal flagellum. A capsule, according to the same observer, or the appearance of a capsule, can generally be made out, especially in those bacilli which are present in the blood. The bacillus is readily stained by aniline dyes, the extremities taking on a deeper colour than the interpolar part. It is usually decolorized by Gram.

Culture characters.—When sown on blood serum and kept at body temperature, in from twenty-four to forty-eight hours an abundant moist, yellowish-grey growth is formed without liquefaction of the culture medium. On agar, but better on

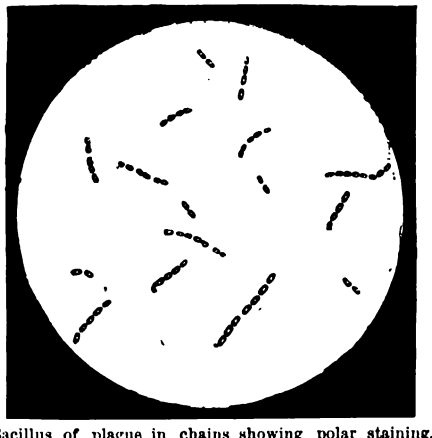


Fig. 66.—Bacillus of plague in chains showing polar staining. From a young culture in bouillon. × 1000. (*Muir and Ritchie.*)

glycerine agar, the growths have a greyish-white appearance. In agar plate cultures they show a bluish translucence, the individual colonies being circular, with slightly irregular contours and a moist surface; on mannite neutral-red-bile-salt agar the colonies are bright red, but are colourless on a similar medium in which lactose is substituted. Litmus-milk and glucose-broth are rendered slightly acid, lactose-broth is unchanged. Young colonies are glass-like, but older colonies are thick at the centre and more opaque; they are singularly coherent and may be removed *en bloc* with a platinum needle. Stab cultures show after one or two days a fine dust-like line of growth. According to Yersin, when sown on gelatin the bacillus gives rise to white transparent colonies which, when examined in reflected light, present iridescent borders.

In bouillon the cultures present a characteristic appearance; the liquid remains clear, whilst a granular deposit takes place on the sides and bottom of the tube. Cultivated on broth in which clarified butter or coco-nut oil is floated, *B. pestis* presents characteristic stalactite growths which gradually fall off, forming a granular deposit. Examined with the microscope, these various cultures show chains of a short bacillus, presenting here and there large bulbous swellings. In gelatin the bacilli sometimes form fine threads, sometimes thick bundles made up of many laterally agglomerated bacteria. The bacillus does not produce spores.

The most favourable temperature for culture is from 36° to 39° C.

Intensification and attenuation of virus.—There can be no question that, both by artificial means and in a natural way, the virulence of the bacillus of plague is susceptible of modification. It has been remarked in Russia, in Persia, and in Calcutta that certain outbreaks of plague were preceded by a sporadic or epidemic febrile, sometimes afebrile, affection, in the course of which the lymphatic glands became enlarged and perhaps suppurated. Cases of this nature, in which a bacteriological examination proved that a cocco-bacillus was present in the blood and enlarged glands, are recorded by Drs. Cobb and Simpson. It is further known that in some instances the virulence and case-mortality of a plague epidemic show a tendency to decrease, the early cases being the most frequently and most rapidly fatal.

Recent observations in India have brought to light a form of chronic plague in rats, in which the specific bacterium, without seriously affecting the health of the animal, remains latent for long periods in abscesses in connection with spleen, liver, or abdominal lymphatics. Although thus latent, it is potentially virulent, proving lethal when cultures obtained from these abscesses are injected into other animals. These facts seem to indicate that under certain unknown natural conditions the virus tends to acquire increased potency, whilst in other circumstances its virulence tends to diminish.

This conjecture is countenanced by the results of experiment on animals. It has been shown that by

passing the virus by inoculation from one guineapig to another the rate of its action becomes accelerated. On the other hand, Yersin remarks that, although it is difficult to start a gelatin-peptone cultivation, nevertheless, when obtained, such a cultivation—at all events certain parts of such a cultivation—will be found to be quite as lethal as virus derived directly from a bubo. He further observes that in such cultures a proportion of the colonies develop more rapidly than others; that if inoculation is made from these more rapidly developed colonies, virulence is found to be diminished; and that if these rapidly growing cultures are frequently repeated, in the long run they cease to be fatal to guineapigs, although they may still prove fatal to white mice.

These and other natural and experimental data indicate a very pronounced tendency to mutability as regards virulence on the part of the plague bacillus: a disposition which, in the future, may very well be turned to important practical account.

It would appear that the gravity of an attack of plague is not affected by the amount of virus introduced. Barber, using an ingenious apparatus, infected guineapigs, each with a single bacillus. The resulting disease was as fatal as that produced by an injection of 500 bacilli.

Experimental plague. *Inoculation.*—Intentional and unintentional experiments have proved the inoculability of plague in man. Whyte in 1802 communicated the disease to himself, and died of it. At Cairo, in 1835, two condemned criminals were inoculated from the blood of plague patients; they contracted the disease, but recovered. The value of these experiments, as proving inoculability, is somewhat depreciated by the circumstance that they were made in the presence of an epidemic of the disease. Ordinary methods of infection cannot be said, therefore, to have been absolutely excluded. For the same reason the cases of Aoyama and his assistant, who were believed to have contracted the disease from dissection wounds, cannot be held as proving that plague is inoculable in man. The deplor-

able accident in a Vienna laboratory, in October, 1898, by which fatal plague of a pneumonic type was acquired—in what way is not exactly known—from manipulations with plague cultures, goes far to complete the little that was wanting in the chain of evidence that this disease is caused by the introduction of the specific bacillus into the human body. The unintentional experiment, in this instance at all events, was not vitiated by having been made in the presence of a plague epidemic.

There is no reason for supposing that man differs in this respect from the lower animals, many of which are exceedingly susceptible to inoculation. Mice, rats, guineapigs, and rabbits are invariably killed if successfully inoculated from the buboes* of plague patients. They present on dissection characteristic lesions with numerous bacilli in the lymphatic glands, blood, spleen, and other viscera. Guineapigs die in from two to five days after inoculation, mice in from one to three days. Calves and swine are susceptible to inoculation, and so are monkeys and many other animals.

In the case of the guineapig, within a few hours of the introduction of the virus a considerable amount of œdema is already apparent around the puncture, and the adjacent gland is perceptibly swollen. At the end of twenty-four hours the animal is very ill; its coat is rough and staring, and it refuses food. Presently it falls on its side and becomes convulsed, one fit following another with increasing frequency as death approaches. If the body is opened immediately after death a rosy-red sanguineous œdema is found at the point of inoculation, with hæmorrhagic inflammatory effusions around the nearest lymphatic gland, which is much swollen and full of bacilli. The intestines are hyperæmic; the adrenals, kidneys, and liver are red and swollen. The much enlarged spleen frequently presents an

* The pus from a bubo is not always infective. Inoculation made with such may fail. Apparently the bacteria of suppuration may kill out the *Bacillus pestis*.

eruption of small whitish granulations resembling in appearance miliary tubercles. All the organs, and even any serous fluid that may be present in peritoneum or pleura, will be found to contain plague bacilli. In the blood, besides those free in the liquor sanguinis, bacilli are to be found in the mononuclear though not, it is said, in the polynuclear leucocytes.

Feeding experiments.—Rats or mice fed on cultures of plague bacilli, or on fragments of the liver or spleen of animals dead of plague, acquire the disease, and generally die with the characteristic symptoms and lesions. Similarly, as has been shown by Simpson, pigs, calves, sheep, monkeys, hens, pigeons, turkeys, geese, and ducks are affected with plague when fed on plague material. The type of plague induced by feeding is the septicæmic. The disease thus induced may be either of an acute or of a chronic nature. When the latter, it may be ill defined and not easily recognized. Thus, pigs may show no marked signs of illness until a month after feeding on infective material, and then only a few days or hours before death. Susceptibility to plague of the animals of the farmyard, and the chronicity and ill-defined nature of the disease which not infrequently occurs among these animals, as well as in rats, are likely to be important factors in continuing the disease in those endemic centres where people, cattle, pigs, and poultry, in addition to the ordinary domestic vermin, are housed under the same roof, and even in the same room.

Rôle of the rat in plague.—Although small and circumscribed epidemics of plague may occur without the intervention of the rat (Hossack), there can be no doubt that in most epidemics of the bubonic form this ubiquitous rodent plays an important part, both in the introduction and in the spread of the infection. The species principally concerned are *Mus decumanus* and *Mus norvegicus* (the grey rat) and *Mus rattus* (the black rat). The bandicoot and musk rat are of little importance in these respects, although susceptible to the infection. In Bombay the epizootic appears first in the *Mus*

decumanus community, *Mus rattus*—the more domestic species—being subsequently attacked. Later the disease appears in epidemic form in man. (Chart 5.)

The seasonal prevalence of bubonic plague in rats

Chart 5, showing progress of plague in rats and mice. (*After Glen Liston.*)

..... Infected *M. decumanus*.
——— Infected *M. rattus*.
▬▬ Human deaths from plague.

is marked, and is not due to a periodicity in their reproduction, but is connected with periods in which fleas are most numerous.

The ancients were well aware of the connection between plague and the rat. In the Bible

the rat is mentioned in association with the plague which broke out amongst the Philistines after they stole the Ark of the Covenant. The Greeks of Asia Minor worshipped a rat-killing Apollo who was reputed to bring and remove plague epidemics. Sambon describes a coin of Lucius Severus, struck at Pergamum in Asia Minor at the time of a great plague epidemic. On the obverse of the coin is the god of medicine, Æsculapius, having at his feet a dead rat and at his side a naked human figure in an attitude of terror or supplication. Mediæval literature likewise contains abundant proof that the association of rats with plague was well recognized even in the dark ages. Many modern observers also have remarked the great mortality among rats and other animals which generally precedes and accompanies outbreaks of plague in man. When writing about the mortality among rats during the recent Canton epidemic, Rennie remarks that the Chinese regarded this unusual and striking occurrence as a sure indication of an extension of the epidemic. From districts of the city where the plague had been raging for some time the rats entirely disappeared, whilst they kept on dying in other quarters to which the disease afterwards spread. The rats, he says, would come out of their holes, in broad daylight even, and tumble about in a dazed condition and die. In a very short time one Chinese officer alone collected upwards of 22,000 dead rats.

Glen Liston states that in places in which plague epidemics keep recurring year after year the local rats acquire a considerable degree of immunity, and, moreover, that this immunity is transmitted hereditarily. Thus in plague-free towns in India—e.g. Madras and Dacca—plague-inoculated *Mus rattus* gave a mortality of 90 to 100 per cent.; in plague-stricken towns—e.g. Cawnpore and Poona—it was only 20 to 40 per cent.

Another observation, already referred to, which together with the foregoing may have important bearings on the spread of plague and the yearly recurrence of epidemics in the same place, is to the effect that

in certain rats the disease may assume a chronic form, the bacillus becoming more or less latent in the lymphatic glands, at the same time being capable of resuscitation into active pathogenicity.

Rocher states that in Yunnan the mortality among the rats is particularly noticeable. Other animals also die, he says; oxen, sheep, deer, pigs, and dogs are all attacked at times, the dog less severely and less frequently than the others.

Pringle says that in Shurwal, Himalayas, where in 1864 plague was epidemic, the rats quitted the various villages in anticipation of the advent of the disease, and that the people, taught by experience, on seeing this exodus recognized it as a warning.

Clemow has pointed out the connection of Mongolian and Siberian plague epidemics with the occurrence of the disease in a species of marmot, called tarbagan (*Arctomys bobac*), common and much hunted in these regions. This animal can harbour the plague bacillus in its body without apparently suffering any ill effects during hibernation, thus constituting a more or less permanent reservoir of the plague virus.

Schurupoff reports the ground squirrel of the Caucasus (*Spermophilus guttatus*) as being extremely susceptible to plague infection, and as probably concerned in the spread of the disease in that region. In California the ground squirrel (*Citellus beechyi*), although it does not live near human habitations, infects rats that do, and thereby acts as an important reservoir of *B. pestis*. It has been ascertained that in this instance the flea, *Hoplopsyllus anomalus*, which infests both animals, acts as the carrier of the plague bacillus from one to the other, the infection being ultimately transmitted to man by the rat fleas (*see* below).

These and many similar facts observed in Bombay, Sydney, Cape Town, and Hong Kong with regard to plague in the lower animals throw important light on one of the ways in which the disease is spread. They, together with the results of the several experiments already alluded to, have to be reckoned with in the

future, more than they have been in the past, in devising schemes of quarantine and in attempts at stamping out the disease in already affected localities. The wholesale destruction of domestic vermin should go hand in hand with the isolation of plague-stricken patients.*

The rôle of the flea in plague.—Yersin placed in the same cage healthy and plague-inoculated mice. The latter died first; but later the originally healthy uninoculated mice also succumbed—proving that plague is communicable either through the atmosphere, by contact, or by ectozoa.

Yersin's experiment has been successfully repeated again and again, on mice, rats, guineapigs, and monkeys, and with many modifications. The result has been indisputable confirmation of Yersin's results, and further proof that bubonic plague is not communicable from animal to animal by simple contact or by atmospheric convection, but that it is readily communicated by ectozoa, especially rat fleas —principally *Xenopsylla cheopis* † (Fig. 67)—which act as passive intermediaries and carriers of the bacillus. Zirolia and others have found that *Bacillus pestis* multiplies in the stomach of the flea, retaining its virulence for over twenty days and being passed

* It is stated that the handling of a rat newly dead of plague is fraught with danger, whereas a rat that has been dead for some time and is cold and stiff may be touched with impunity; and it is surmised that the fleas of the newly dead rat are still in its fur, and quit it for the body of the manipulator, carrying on their probosces the bacilli of the disease, which they introduce when they proceed to feed on their new host. When a rat has been dead for some time and the body is cold, the fleas have already forsaken it; hence the impunity with which the rat itself may be handled, but the danger of the locality in which it died and where the hungry infected fleas are awaiting an opportunity for a meal. The fact that the glands of the legs are usually the first to become implicated in the majority of cases of plague suggests that the virus is generally introduced through the skin of the feet or legs, which are just those parts most likely to be attacked by a flea picked up in walking across the floor of a room in which plague-stricken rats or other animals have died.

† This is the rat flea in the tropics. *Ceratophyllus fasciatus* which attacks men as well as rats, is the rat flea in temperate climates. Plague epizootics occur in mice, but are not associated with plague in man. *Ctenopsylla musculi* does not readily feed on man.

out in the fæces; so that the flea serves not only as a carrier, but also as a multiplier of the germs.

Especially convincing are the experiments of the Indian Plague Commission,* which clearly show that if fleas are excluded healthy rats will not contract the disease, even if kept in intimate association with plague-infected rats. Young rats may even be suckled by their plague-stricken mothers and remain healthy. But if fleas are introduced, whether naturally or intentionally, into the field of experiment, plague at once begins to spread from rat to rat, and with a rapidity in proportion to the number of fleas present. The Commission has shown further that an epizootic of rat plague may start without contact or even proximity of healthy and infected animals. It suffices to transfer fleas from a plague animal on to a healthy animal, or to place the latter in a room in which plague rats have died recently and been subsequently removed. The fleas that have left the body of the dead rats, remaining in the room, convey the germs. The atmosphere of the room is not infective; for if the experimental animal be suspended in an open cage a few feet above the floor, it does not become infected. Nor is the animal infected if placed on the floor, if the precaution be taken to surround the cage with "tangle foot" so as to keep off the fleas. But if it be placed on the unguarded floor, either in its cage or allowed to run about, or even if it be suspended two inches above the floor—a distance not beyond the saltatory powers of the flea—it will become infected. The Commission obtained practically the same results in experiments with guineapigs in plague-infected houses. It is therefore no longer open to question that the important—probably the most important—agents in the development and perpetuation of plague epidemics are

Fig. 67.—Xenopsylla cheopis.

* *Journal of Hygiene*, Vol. VI., No. 4, April, 1906.

the rat, and the rat flea, *Xenopsylla cheopis*, and other fleas, such as *Ctenocephalus canis* (Fig. 68), which is known to bite dog, man, and rat indifferently. This important conclusion is completely supported by the elaborate epidemiological observations of Ashburton Thompson in Sydney, who has shown that the rat-flea theory best explains the behaviour of epidemic plague—at all events in that city.

The flea communicates the plague bacillus either on its fouled mandibles, or by regurgitation of the contents of its stomach during the act of sucking, or by provoking scratching and consequent inoculation of the bacilli deposited in its fæces on the skin.

C. J. Martin's recent observations on plague-infected fleas are of great interest. He found that a proportion of the fleas fed on plague-infected rats develop a peculiar pathological condition of stomach and œsophagus, these organs becoming blocked with blood-clot containing a pure culture of *B. pestis*. When such a flea feeds on a normal rat, part of the culture regurgitates and communicates infection; at the same time bacilli are passed in the fæces and may infect through any existing abrasion. He further observed that the "blocked" fleas died very rapidly if placed in a warm, dry atmosphere, apparently of thirst. (Figs. 69, 70.)

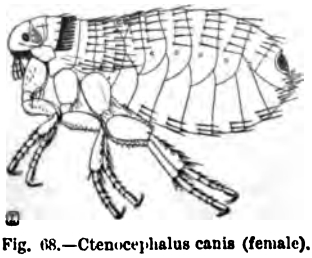


Fig. 68.—Ctenocephalus canis (female).

In temperate climates fleas are most numerous during the warmer seasons of the year; hence summer and autumn is the bubonic plague season in such climates. In warm climates bubonic plague is most prone to become epidemic at those times of the year in which temperature ranges between 10° and 30° C. —temperatures favourable to the multiplication and activity of the flea. Temperatures over 30° C. are unfavourable to the flea, especially if the atmosphere is

dry. Pneumonic plague, not being spread by the flea, is not influenced by temperature in this way (*see* p. 336).*

Bionomics of the rat flea.—In ordinary circumstances the rat flea completes its developmental cycle in fourteen days to three weeks, but in warm, damp weather this may be shortened to ten days. The average life of a flea, apart from its host, is about ten days, but it is capable of remaining alive without food for two months, should the temperature of the

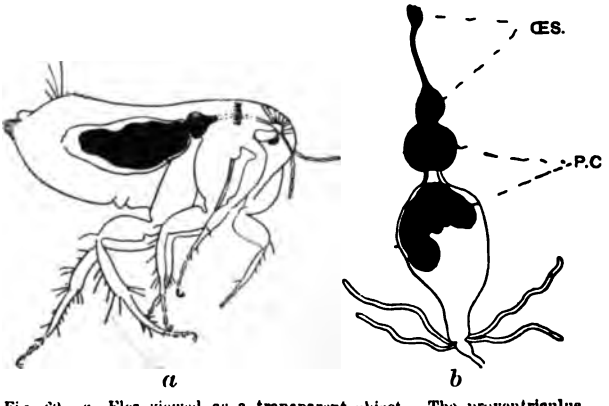


Fig. 69.—*a*, Flea viewed as a transparent object. The proventriculus and stomach contain a mass of plague culture. *b*, Flea's stomach obstructed by growth of plague culture.

ŒS., Distended œsophagus containing fresh blood; P.C., obstructing mass of plague culture.

air be low at the time. In tropical temperatures the insect can harbour the plague bacillus without feeding on blood for forty-five days.

Apart from the very serious danger arising from vermin affected with chronic plague, which may hang about a house for a long time, it would appear that the house itself does not retain the infection for any length of time. The Plague Commission has shown that floors of cow-dung if contaminated with *Bacillus pestis* do not remain very infective for more

* Though it is possible to transmit plague experimentally by means of the human flea, *Pulex irritans*, yet this flea plays little or no part in the spread of plague at the present day.

than forty-eight hours, and that floors of chunam cease to be infective in twenty-four hours.

Conditions favouring naturally acquired plague.—The most potent circumstances which predispose to the epidemic outbreak of plague are extreme filth and overcrowding. In such circumstances the virus, once introduced, tends to spread. These conditions, however, are not all-sufficient, for even in the filthiest and most crowded oriental towns, and without any apparent

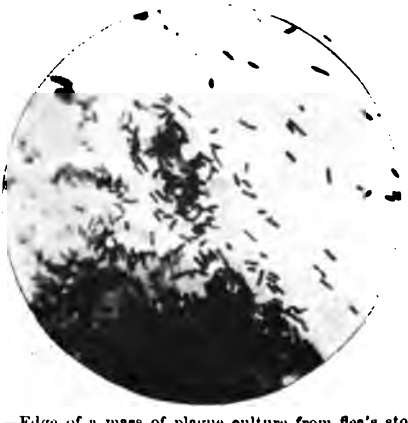


Fig. 70.—Edge of a mass of plague culture from flea's stomach. Microphoto × 1,000.

Figs. 69 and 70 illustrate the method of transmission of *B. pestis* by *Ceratophyllus fasciatus*. (*By kind permission of Dr. C. J. Martin, Journ. of Hyg. 3rd Plague Suppl., Jan.*, 1914.)

alteration in the habits or circumstances of the population, the disease, after having become epidemic, dies out spontaneously. It may be difficult to indicate the exact way or ways in which filth and overcrowding operate; but certain it is, as experience has shown, that in good sanitary conditions plague does not spread even if introduced, and that in opposite conditions it may for a time spread like wildfire.

Filth and overcrowding imply close proximity of the sick and the healthy; an atmosphere saturated with the emanations of the sick; a lowered tone of

the general health; saturation of the soil and of the surrounding media with animal refuse; abundance of body vermin of all kinds, as well as of other vermin, such as rats and mice, which serve as multipliers of the virus; carelessness about personal cleanliness, about wounds of the hands and feet, about clothing, and about food, dishes, and water. One can understand how in such circumstances the germ has opportunities to multiply and spread.

Except in the case of the relatively rare pneumonic form, plague, though "catching," is not nearly so contagious as are scarlet fever, measles, or small-pox. Medical men, and even nurses, in clean airy hospitals rarely contract the disease, provided they have no open wounds and do not remain too long in close proximity to their patients. In cities the cleanly districts are generally spared. This was well exemplified in the recent epidemics at Canton and Hong Kong, where the airy, cleanly European quarters and the relatively clean, well-ventilated boat population were practically exempt, whilst the disease ran riot in the adjoining filthy, overcrowded native houses only a few yards away.

The fact that plague can be communicated to the lower animals by feeding them on the tissues of plague patients and on cultures of the specific bacillus, suggests that the disease may be conveyed to man in food or drink. The bacillus is sometimes found in the intestinal contents of patients. It is also to be found in the urine. Water or food contaminated with sewage or fæcal matter may therefore be regarded as a possible medium of infection. Food contaminated by infected rats is likely also to be a source of danger. In the epidemic of 1902, in Hong Kong, plague bacilli were found in the intestinal contents and mucus of the mouth in about one-third of the plague-infected rats examined, and in the urine in about one-fifth of the cases (Simpson).

The bacilli do not, as a rule, penetrate the unbroken epidermis, as proved by the impunity with which post-mortem examinations in plague cases have often been made; but it seems not improbable th

in a proportion of instances the plague germ is introduced through trifling wounds of the feet. It is conceivable that such germs as may be lying about on the ground, deposited there in the discharges of sick human beings or of plague-stricken animals, or perhaps growing there in natural culture, may be picked up in this way. The frequency with which the primary bubo, as will be pointed out, is located in the deep femoral glands favours this idea. One can understand, too, how lice, fleas, bugs, and perhaps flies might act as carriers of the virus from person to person, inserting it with their bites, or inducing scratching and superficial skin lesions, through which the virus obtains entrance.* Yersin found that the flies in his Hong Kong plague laboratory died in great numbers, their bodies being crowded with the specific bacillus; he injected bouillon containing a trituration of one of these flies into a guineapig, and the animal presently died with all the signs of plague. Sablonowski, who in 1884 in a measure anticipated the discovery of the bacillus by Kitasato and Yersin, remarked that during the Mesopotamian epidemic of that year a certain species of fly appeared and disappeared concurrently with the plague; he considered that this insect was an active agent in spreading the disease.

That the plague bacillus does at times enter the body through the unbroken skin or mucous membrane is made highly probable (1) by the absence in the great majority of cases of human plague of evidence of an initial skin lesion; (2) by the success of experimental feeding of animals with plague tissues or cultures; (3) by the ease with which infection is conveyed through the air to man and other animals in pneumonic plague; and (4) by the certainty with which rats can be infected by simply smearing a plague culture on the shaven skin.

Age, *sex*, and *occupation* have very little influence in plague. The youngest children are susceptible;

* The origin of the epidemic of plague at Saraitschikow, in the Ural Province, Russia, in which 415 persons lost their lives, may be accounted for in this way. A rich Cossack died, presumably of plague. After his funeral his clothes were distributed.

old age seems to be to a certain extent protective, the disease being rarer after 50 than during adolescence. Women, doubtless on account of their remaining much indoors in the tainted surroundings, are relatively more frequently attacked than men.

Geological constitution of soil appears to have no direct influence on plague.

Atmospheric temperatures if very high or very low seem to have a repressing effect. Thus, as a rule, epidemics in Egypt and Mesopotamia declined during the height of the very hot and dry summer, and in Europe during the extreme cold of winter. On the other hand, plague on more than one occasion has flourished during a Russian winter, and also, as in Hong Kong recently, during the heat of a tropical summer. On the whole, the evidence points to moderate temperatures—50° to 80° F.—combined with a certain degree of dampness as being the principal atmospheric condition favouring epidemic outbreaks and recurrences. Manifestly any influence temperature may have is only an indirect one.

In large towns, and in some districts, in which plague recurs for several years in succession, there is a seasonal periodicity (which may not be the same in all places) of maximum and minimum prevalence.

Elevation, as regards sea-level, does not directly affect the general distribution of the disease. Indeed, mountain tribes, probably on account of their poverty and squalor, are peculiarly liable to epidemics. In houses the ground floor is more dangerous than are the upper storeys.

The *duration of epidemics of plague* is very variable. In large cities—Bombay, Hong Kong, Canton, for example—when fairly established the disease may not relax its grip for ten or more years. In smaller places it may disappear in a few months.

The *extension of plague epidemics* is peculiar, and in many respects resembles that of cholera. It follows trade routes. Sometimes it may spread rapidly from point to point; more generally it creeps slowly from one village to another, from one street or one house to another. Sometimes it skips a ho

a village, or a district, to appear there later on. Particular houses, and even particular floors of houses, may be infected, whilst neighbouring ones remain free from the disease.

These and many other facts in the epidemiology of plague are probably to be explained by the connection of the disease with the rat flea. When we have fuller information about the migrations of the rat, the breeding seasons of the rat flea, the influence of food and temperature and other circumstances on these animals, it is reasonable to expect that our knowledge of the principles that underlie the transmission, the spread, and decline of plague will be more satisfactory than it is at present.

Symptoms. *Incubation period.*—Symptoms of plague begin to show themselves after an incubation period of from two to eight days. It is said that in certain very rare instances the incubation period may extend to as much as fifteen days. It is also said that in highly malignant epidemics the disease may declare itself within three or four hours from the time of exposure to infection.

Prodromal stage.—In a certain but small proportion of cases there is a prodromal stage characterized by physical and mental depression, anorexia, aching of the limbs, feelings of chilliness, giddiness, palpitations, and sometimes dull pains in the groin at the seat of the future bubo.

Stage of invasion.—Usually, the disease sets in somewhat suddenly with fever, extreme lassitude, frontal or, more rarely, occipital headache, aching of the limbs, vertigo, drowsiness or perhaps wakefulness, or troubled dreams. Rigor is rarely a marked feature; more often the disease is heralded by feelings of chilliness. The face quickly acquires a peculiar expression, the features being drawn and haggard, the eyes bloodshot, sunken and staring, the pupils probably dilated; sometimes the face wears an expression of fear or horror. The patient, when he can walk, drags himself about in a dreamy sort of way, or he staggers like a drunken man. There may

be nausea and vomiting; in some instances there is diarrhœa.

Stage of fever.—The stage of invasion may last for a day or two without a serious rise of temperature occurring. Usually it is of much shorter duration; or it may be altogether wanting, the disease developing abruptly without definite rigor or other warning, the thermometer rising rapidly to 103° or 104°, or even to 107° F., with a corresponding acceleration of pulse and respiration. The rise of temperature is more gradual than is usual in malarial fevers. The skin is now dry and burning, the face is bloated, the eyes are still more injected, sunken and fixed, the hearing is dulled. The tongue is swollen and covered with a creamy fur, which rapidly dries and becomes brown or almost black; sordes form on the teeth and about the lips and nostrils. Thirst is intense, prostration extreme, the patient from utter weakness being hardly able to make himself heard. Sometimes the patient becomes delirious; more generally he sinks into a state of typhoid stupor and prostration, perhaps picking the bedclothes or trying to catch imaginary objects. The delirium is sometimes wildly furious, sometimes fatuous, sometimes of a low muttering type. Coma, convulsions—sometimes of a tetanic character—retention of urine, subsultus tendinum and other nervous phenomena may occur. Vomiting is in certain cases very frequent; some are constipated, others have diarrhœa. The spleen and liver are usually both enlarged. Urine is scanty, but rarely contains more than a trace of albumin. The pulse, at first full and bounding, in the majority of cases rapidly loses tone, becoming small, frequent, fluttering, dicrotic, intermittent. In the later stages the heart may be dilated, the first sound being feeble or absent. In many cases, as death approaches, there may be some cyanosis.

Stage of adenitis.—In from about two-thirds to nine-tenths of the cases, some time between the first few hours and the fifth day, generally within twenty-four hours, the characteristic bubo or buboes de[illegible] Usually (in 70 per cent.) the bubo forms in the [illegible]

most frequently on the right side, affecting one or more of the femoral glands; less frequently (20 per cent.) it is the axillary glands, and still more rarely (10 per cent.), and most commonly in children, it is the glands at the angle of the lower jaw that are affected. The buboes are usually single; in about one-eighth of the cases, however, they form simultaneously on both sides of the body. Very rarely are buboes formed in the popliteal or in the epitrochlear elbow glands, or in those at the root of the neck. Occasionally buboes occur simultaneously in different parts of the body.

The buboes vary considerably in size. In some instances they are not so large as a walnut; in others they attain the size of a goose's egg. Pain is often very severe; on the other hand, it is sometimes hardly complained of. Besides the enlargement of the gland, there is in most instances distinct infiltration of the surrounding connective tissue.

In a very small proportion of cases what are usually described as carbuncles, but which are in reality small patches of moist gangrenous skin that may gradually involve a large area, develop on different parts of the integument. These occur either in the early stage or late in the disease. Sometimes they slough and lead to extensive gangrene.

In favourable cases, sooner or later, after or without the appearance of the bubo, the constitutional symptoms abate with the setting in of profuse perspiration. The tongue now begins to moisten, the pulse-rate and temperature to fall, and the mild delirium, if it has been present, to abate. The bubo, however, continues to enlarge and to soften. After a few days, if not incised, it bursts and discharges pus and sloughs—sometimes very ill-smelling. In rare instances suppuration is delayed for weeks; whilst in some the bubo subsides after a few weeks, or perhaps months, without having broken down. Convalescence, when it occurs, sets in some time between the sixth and tenth day, although it may be delayed for a fortnight or three weeks. Occasionally a pyæmic condition, with boils, abscesses, cellulitis, parotitis, or

secondary adenitis, succeeds the primary fever. The sores left by the buboes and abscesses of plague are extremely indolent, and may take months to heal.

Hæmorrhages of different kinds are not an unusual feature of plague. Ecchymotic effusions of a purplish or dull-red tint, and varying in size from a hemp-seed to spots half an inch in diameter, are very often found scattered in greater or less profusion over the skin, especially on exposed parts of the body and at the sites of insect bites or of wounds. Larger patches of cutaneous hæmorrhagic effusion are rare. There may be bleeding from the nose, mouth, lungs, stomach, bowel, or kidneys. Hæmorrhages occur with marked frequency in certain epidemics; they are regarded as evidence of great malignity. Especially malignant are those epidemics in which hæmoptysis, or pneumonia, is a common occurrence.

Abortion almost invariably occurs in pregnant women; the fœtus sometimes shows signs of the disease.

Death may take place at any time in the course of plague. Usually it occurs between the third and fifth day, with symptoms of profound adynamia, heart failure, or perhaps from convulsions, from coma, from internal hæmorrhage, or, later, from exhaustion consequent upon prolonged fever or suppuration, or from secondary hæmorrhages.

On the other hand, in a certain proportion of cases convalescence sets in and proceeds more or less rapidly. Generally it is a tedious affair, being prolonged by suppuration, sloughing, and similar complications.

The foregoing description applies more especially to the ordinary *bubonic* (as it is called) type of the disease. Of late, certain other forms of plague have received individual recognition in consequence of their extreme virulence and, in the case of one of these forms, of its high degree of communicability. These forms are called respectively *septicæmic* and *pneumonic*.

Septicæmic plague, sometimes cal[illegible] **siderans.**—In this type there is no spe[illegible]

ment of the lymphatic glands apparent during life, although after death the glands throughout the body are found to be somewhat enlarged and congested. The high degree of virulence and rapid course of the disease depend on the entry of large numbers of the bacilli into the blood, where they can be readily found during life. The patient is prostrated from the outset; he is pale and apathetic; there is no, or very little, febrile reaction (100° F.). Great weakness, delirium, picking of the bedclothes, stupor, and coma end in death on the first, second, or third day. Frequently in these cases there are hæmorrhages.

Pneumonic plague.—This type of the disease, which was carefully studied by Childe and others, is especially dangerous as well as deadly: dangerous because of the multitude of bacilli which are scattered about in the patient's expectoration,* and because the clinical symptoms are unlike those of typical plague, and are apt to be mistaken for some ordinary form of lung disease. The illness commences with rigor, malaise, intense headache, vomiting, general pains, fever, and intense prostration. Cough and dyspnœa set in, accompanied by a profuse watery blood-tinged sputum. The sputum is not viscid and rusty, as in

* During the epidemic of pneumonic plague in Manchuria from October, 1910, to March, 1911, R. P. Strong and Teague exposed 82 agar plates at distances varying from 5 cm. to 2 metres in front of the faces of plague patients for a period of two minutes. In 39 instances the patient did not cough, and only 1 of the plates yielded plague bacilli. In 35 instances the patient coughed: the corresponding plates yielded plague cultures in 15 instances, the growths having originated in the invisible spray.

The vitality of the plague bacillus outside the body depends in great measure on the rate of evaporation, that is to say, on the temperature and hygrometric conditions of the air. Thus in Harbin the bacillus retained its vitality for long periods when the thermometer stood at —9° C. and the water deficit equalled about 0·3 mm. of mercury. In India, where evaporation goes on much more rapidly at temperatures perhaps of 30° C. and water deficit of 9·5 mm. of mercury, pneumonic plague is much rarer, amounting to only 3 per cent. of the total cases. In Manchuria there were only two or three cases of bubonic plague in a total of some 50,000 deaths.

The initial case of this epidemic is said to have been that of a tarbagan hunter, who contracted his infection in skinning one of these animals. Domestic animals, donkeys and dogs were attacked during the epidemic and contributed to its spread.

ordinary pneumonia. Moist râles are audible at the bases of the lungs, the breathing becomes hurried, other symptoms rapidly become worse, delirium sets in, and the patient dies on the fourth or fifth day. This is the most fatal as well as the most infectious form of plague.

Abortive or larval plague (pestis minor, pestis ambulans).—Certain epidemics are distinguished by the large proportion of mild cases. In such, buboes form and suppurate or resolve, the associated constitutional symptoms being comparatively mild, or perhaps altogether wanting. In every epidemic there may be cases in which the patient is able to be about, having little if any fever, and apparently being little inconvenienced by the disease. Such cases, however, may collapse suddenly.

The occurrence of epidemics of bubo with little or no constitutional symptoms, which precede and follow true plague, has already been alluded to (p. 334). These cases are of great importance in their bearing on the spread and prevention of the graver form of the disease.

Relapses, though rare, do occur, and are dangerous.

Mortality.—The case-mortality of bubonic plague varies in different epidemics. It is usually greatest at the beginning and height of the epidemic. Disregarding those mild epidemics just alluded to, the death-rate may be anything from 60 to 95 per cent. of those attacked. Much appears to depend on the social condition of the patient and the attention and nursing available. Thus in a recent Hong Kong epidemic, whilst the case-mortality among the indifferently fed, overcrowded, unwashed, and almost unnursed Chinese amounted to 93·4 per cent., it was only 77 per cent. among the Indians, 60 per cent. among the Japanese, and 18·2 per cent. among the Europeans, a gradation in general correspondence with the social and hygienic conditions of these different nationalities. In the South American epidemics and in the recent circumscribed epidemics in Europe the mortality was only about one-third of that obtaining in I

China. Pneumonic plague is invariably fatal in from three to four days.

Pathological anatomy and pathology.—After death from plague the surface of the body very frequently presents numerous ecchymotic spots or patches. The number and extent of these vary, apparently, in different epidemics. Sometimes—as in the Hong Kong epidemic of 1894—they are few and trifling, having their origin, as mentioned, principally in insect bites. In other epidemics, according to their historians, the cutaneous hæmorrhages have been both extensive and numerous; hence the name "black death" formerly applied to this disease. The characteristic buboes are generally apparent; occasionally there are also furuncles, pustules, and abscesses. Rigor mortis is usually moderate; sometimes post-mortem muscular contractions, like those of cholera, take place. Post-mortem rise of temperature is often observed. Decomposition is said to set in early.

The characteristic appearance in a necropsy of plague is that of engorgement and hæmorrhage, nearly every organ of the body participating more or less. There is also parenchymatous degeneration in most of the organs. The brain, spinal cord, and their meninges are markedly congested, and there may be an increase of subarachnoid and ventricular fluid. There are numerous and pronounced puncta cruenta on the brain sections; occasionally there may be considerable extravasations of blood into the substance of the brain (mesocephalon and medulla oblongata).

Ecchymoses are common in all serous surfaces; the contents of the different serous cavities may be sanguineous. Extensive hæmorrhages are occasionally found in the peritoneum, mediastinum, trachea, bowel, pelvis of kidney, ureter, bladder, or in the pleural cavities. The lung frequently shows evidences of bronchitis and hypostatic pneumonia; sometimes hæmorrhagic infarcts and abscesses are found. The right side of the heart and the great veins are usually distended with feebly coagulated or fluid blood. In pneumonic plague the superficial lymphatic glands are not enlarged; the pleural cavities contain blood-

stained serum; the infected lungs are deeply congested and œdematous, and at a later stage pneumonic consolidation is found. The bronchi contain blood-stained serum and the bronchial glands are swollen and hæmorrhagic.

The liver is congested and swollen, and its cells are degenerated. The spleen is enlarged to two or three times its normal size. The mucosa of the alimentary canal as a whole is congested, showing here and there punctate ecchymotic effusions and, occasionally, hæmorrhagic erosions, and even—especially about the ileo-cæcal valve—ulcerations.

Similarly the kidneys are congested, and may exhibit ecchymoses both on the surface and in the pelvis. The perirenal connective tissue also may be congested and infiltrated. The ureters and the mucous surface of the bladder are often found to be sprinkled with ecchymoses, in which cases the contained urine is generally bloody.

Evidence is invariably discoverable of serious implication of the lymphatic system. One, two, or many of the lymphatic glands are inflamed and swollen. Both in and around the glands there is much exudation with hæmorrhagic effusion, hyperplasia of the gland cells, and an enormous multiplication of bacteria. The glands of the groin, of the armpit, and of the neck are particularly affected. On dissection the superficial buboes are very often found to be connected with extensive, deep-seated adenitis extending either through the crural ring or down the neck, and involving the pelvic, the abdominal, or the mediastinal glands, as the case may be. Section of the affected glands will reveal any stage of inflammation from cellular hyperplasia to suppurative softening, according to the period of the disease at which death has occurred. In whatever stage death has taken place, there is always evidence of intense hyperæmia in, as well as around, these glands—a hyperæmia which is specially characterized by a marked tendency to hæmorrhagic effusion. In the earlier stages of the adenitis the specific bacillus is found in the lymph spaces around the follicl

it is found in the follicles themselves, in the lymph spaces, and in the medullary cords (Aoyama).

If death has taken place at a very early stage of the disease, the swelling of the lymphatic glands may not be so evident; but it is rare not to find some gland or glands characteristically affected. In those septicæmic and pneumonic cases in which the bubo is absent nearly all the lymphatic glands of the body are slightly enlarged, pink or dark red in colour. Instead of intense and localized adenitis, a milder but more general enlargement of the lymphatic glands of the entire body is discovered. Sometimes the lymphatic trunks are also markedly implicated.

Diagnosis.—The occurrence of fever and adenitis during a plague epidemic must invariably be viewed with suspicion, and particularly if the fever rapidly assumes an adynamic character. In the early stages diagnosis may be very doubtful, especially in pneumonic plague. The discovery of the bacillus in the glands, blood, sputum, or discharges is the only thoroughly reliable test. A small quantity of the suspected material should be spread on a slide, dried, fixed, and stained with an aniline dye. Should a cocco-bacillus be found with the characteristic bipolar staining, it should be cultivated by Haffkine's method in broth on which clarified butter (ghee) or coconut oil is floated. From the undersurface of the oil, if the bacillus be that of plague, stalactite-like growths of bacilli will form. When disturbed, the stalactite growths break off and fall in snow-like flakes to the bottom of the vessel. No other known bacillus behaves in this way. (*See* p. 316.) In case of doubt, animal inoculation should be had recourse to: a little of the virus from the patient or a culture is rubbed into a shaven area (1 in. square) on the abdomen of a white rat or a guineapig. *B. pestis* inoculated in this way kills the guineapig in seven days, the rat sooner.*

* *Post-mortem indications of plague in the rat.*—Before rats suspected of being plague-infected are handled, they should be immersed in disinfectant to destroy ectoparasites.

The lymphatic glands should be first exposed. If the rat is infected subcutaneous injection around the glands is generally

General prophylaxis.—The prophylaxis of plague, as of other infectious diseases, has to be considered from the standpoint of the community and also from that of the individual. As regards the former, it includes measures for preventing the introduction of the virus, for staying its spread if introduced, and for securing its destruction.

Quarantine.—Modern systems of land or sea quarantine directed against plague take cognizance of the facts that the incubation period of the disease may extend to ten days, and that plague affects certain of the lower animals as well as man. Ten days is the minimum period that should elapse between the time of departure from an infected place, between the date of the last death, or between the arrival of a ship or batch of travellers with cases of plague in progress among them, and the granting of free pratique. Moreover, as Kitasato has shown that the specific bacillus persists in the bodies of those who have recovered from plague for at least three weeks from the cessation of the active disease, convalescents should be isolated for a month before they are allowed to mingle with an uninfected community.

Although Kitasato has stated that the plague bacillus perishes in four days when dried on cover-glasses and protected from sunlight, and in from three to four hours when exposed to sunlight, experience has shown that under certain conditions, as yet unknown, it will survive outside the body for a very much longer period.* There is a considerable mass of evidence tending to show that clothes, skins,

recognizable. If the gland is itself inflamed it is almost diagnostic of plague; in which case the liver will be found of a yellow colour and sprinkled with innumerable pinky-white granules. The spleen is enlarged, congested, and occasionally granular. Serous or blood-stained serous effusions are present in 72 per cent. of such rats. If on microscopical examination of scrapings from glands or spleen bipolar-staining bacilli are detected the case is probably plague. Too great stress must not be laid on bipolar staining, as this feature depends somewhat on the method of staining; it is best demonstrated by Leishman or eosin-azur stain.

* Schurupoff found seven-year-old cultures of *B. pestis* to be still alive. He examined 17 plague corpses a year after death; from 6 of them he recovered the plague bacillus.

textile fabrics, and other similar materials may preserve the virus in an active state for several months. Such articles, therefore, coming from an infected district, more especially if there is any suspicion that they have been soiled by or have been in proximity to plague patients, should be destroyed or thoroughly disinfected.

In ships coming from an infected port the rats, mice, and such-like vermin should be destroyed, thrown overboard, and sunk before harbour is entered. The generation of sulphurous acid gas under pressure, especially the Clayton system, has been found useful for this purpose.

Kitasato found that bouillon cultures of the bacillus were killed in half an hour by a temperature of 80° C., and in a few minutes by steam at 100° C. Growth of the bacillus did not occur in cultures after exposure for one hour to a 1 per cent. solution of carbolic acid. The bacilli are also killed by a three hours' exposure to milk of lime. These facts serve as a guide to suitable disinfectants, of which the best and most practicable are steam, 1 in 1,000 corrosive sublimate in carbol-sulphuric acid, lysol, chloride of lime in 1 per cent. solution, carbolic acid in 5 per cent., formalin 2 per cent.

On plague breaking out in a small village community, so soon as the disease is recognized measures should be taken to prevent the inhabitants leaving the locality and thus spreading the disease. There is little danger of this until the inhabitants become alarmed by a rapid extension of the disease. If possible, after the patients have been isolated in a special hospital, the village should be evacuated for a month, the inhabitants being accommodated in temporary huts close by, while the houses which the patients have occupied and those in their neighbourhood should be disinfected. The safest and most thorough form of disinfection is by fire, and in the case of an isolated village prompt destruction of the infected houses by fire is the surest method of stamping out the infection. The clothes and bedding of all patients should be burned. The

dead, with as little delay as possible, should be buried in deep graves or cremated. Isolated observation camps should be organized, in which "suspects" and "contacts" may be segregated for a time equal at least to the incubation period of the disease. Rats and mice should be poisoned or otherwise destroyed, and their bodies burned. Besides such special measures, general sanitation should be scrupulously carried out. The diffusion of plague by railways must be carefully guarded against.

In the event of an outbreak in a town, it must be borne in mind—first, that there is an intimate connection between rat plague and human plague; second, that rat plague is conveyed to human beings, and, once established in human beings, is communicable to others and to rats by means of the expectoration, by the discharges from the bowels and by the urine, and by discharges from the buboes or glandular swellings; and third, that a plague in rats usually precedes plague in human beings. It is as important to know in what houses, areas, and quarters of the town the rats are infected as it is to know in which of these there are plague patients. In addition, therefore, to prompt notification of plague patients, a system designed to obtain information as to the occurrence of plague in rats should be instituted. It is not sufficient to carry on a general campaign against rats, and to burn all rats which have been poisoned or caught in traps, but it is necessary also daily to examine bacteriologically every rat so destroyed, in order to determine whether it is healthy or infected, and so to differentiate the healthy from the infected parts of the town. A ticket on the rat, giving the address from which it was brought, locates the street and house, and permits of action being taken at once. A house in which a plague rat is found is a plague-infected house, and if plague among the inmates is to be prevented the necessary preventive measures should be taken at once. These measures consist in the evacuation of the house until it has b

disinfected and rendered rat-proof, and the disinfection of the clothes and belongings of the inmates.

For the detection of plague-infected houses guinea-pigs, which do not harbour fleas as a rule, are now employed in Japan and India as convenient traps for rat fleas. The guineapigs are turned loose in houses and warehouses, and rapidly succumb to the disease if plague fleas are present.

In India the compulsory inspection of all dead bodies prior to burial has been found a valuable measure for discovering infected houses and localities.

In all efforts to control the introduction and spread of plague, cases of pestis ambulans must be sought out and treated with as much respect as the more virulent forms of the disease.

It is very questionable if in practice any system of rigid quarantine, no matter how carefully devised and theoretically perfect, is ever absolutely protective. Its working is necessarily at the mercy of a large number of individuals, any one of whom, either from incompetence or from dishonesty, may permit its regulations to be broken through. Even if the introduction of plague by man could be prevented in this way, it is difficult to see how its introduction by rats or mice could be effectually guarded against. Quarantine may, and doubtless does, keep out a proportion of the infected, and to this extent it does some good; but it must be combined with careful general sanitation, with thorough disinfection, with the destruction of all discharges and fomites, with the speedy discovery and isolation of the sick, with the evacuation of infected houses and even of neighbourhoods, and with the wholesale destruction of vermin. These latter things English experience has shown to be far more effective than any system of quarantine; it was only in deference to Continental views that quarantine, in the ancient sense of the word, was practised in Great Britain against plague and yellow fever. A rational quarantine plus rational sanitary measures is what is wanted.

Destruction of vermin and other measures in anticipation of the introduction of plague virus.—

Considering the well-established facts that rats are specially susceptible to plague, that in many epidemics they have been attacked weeks before the disease has shown itself in man, that their habits bring them into intimate association with man, there can be no doubt that these rodents play a very important part in the diffusion of the introduced virus. This being the case, it is reasonable to believe that if the rats were destroyed the risk from the introduction of a case of plague, whether by man, rat, or fomites, would be very much reduced in any community in which this measure had been carried out. The responsible authorities of all towns and villages in active communication with plague centres should, *in anticipation* of the possible advent of the infection, see to the destruction of all rats in their districts, and this in addition to instituting the ordinary measures for dealing with overcrowding, food and water supply, domestic and municipal cleanliness. The destruction of rats is a cheap measure in comparison with those adopted in India and elsewhere, which have so signally failed to arrest epidemic plague. The campaign against rats is usually carried on by the employment of rat-traps and rat-catchers, and the laying down, under precautionary conditions, of poisons such as arsenic and phosphorus. As no one method is satisfactory, it is usual to employ several at the same time. The pumping of SO_2 gas under pressure is useful for ships full of cargo and for warehouses with goods in them. So long as the sulphurous acid gas is dry, and is not used on damp articles, no damage is done to merchandise. Care has, however, to be taken with damp things, as they may get slightly discoloured.

Where possible houses and warehouses should be made rat-proof, not an easy measure considering the burrowing and climbing habits of the rat. *Mus decumanus* can penetrate ordinary lime mortar or soft brick, but is stopped by cement and concrete. Its burrows may attain a depth of 18 in. *Mus rattus* is not so active in this respect. Simpson recommends that walls should be at least 6 in. thick when made of hard brick or concrete, and that they should extend

to not less than 18 in. below the level of the ground floor, and that the latter should be made of concrete 3 in. thick, covered with ½ in. of cement. All ventilators should be protected with iron gratings, and all openings around wires and pipes cemented. The mooring cables of ships should be shielded in such a way as to prevent egress or ingress of rats, and all gangways should be taken up at night or when not in use.

Attempts have been made to set up an epidemic among the rats which should not be communicable to man. For this purpose the bacillus discovered by Danysz was recommended by him. But the method employed—viz. inoculating a few rats with the bacillus and then allowing them to escape, in the hope that when they sickened they would be eaten by other rats, which would in their turn be taken ill, and an epidemic be thus set up—has not been successful. Experiments on these lines have failed. The Danysz bacillus was, however, found to be useful in Cape Town and elsewhere for the destruction of rats when a system introduced by Professor Simpson was adopted, and bread soaked in the cultures was distributed and laid down in the same way as is usually done with biscuits on which rat poison is spread. By distributing thousands of doses an excellent result was obtained, and rats which were examined in the localities where the Danysz bacillus had been used in this way were found to have died from the disease induced by this organism. Rats which had migrated were also found to have died of the same cause in localities other than those in which the cultures were placed. An important point in the success attending these operations was found by Dr. R. W. Dodgson to be the raising and maintenance of the virulence of the cultures. Those sent out from the Pasteur laboratory after a fortnight's voyage were found to be useless, and consequently required to be exalted in virulence by a series of passages through healthy rats.*

* Danysz's bacillus rapidly loses its virulence when grown on the ordinary culture media, but retains it if grown on egg-albumin media, killing rats in from seven to nine days.

Personal prophylaxis.—As regards the individual, all unnecessary visits either to plague patients or to plague neighbourhoods should be avoided and, if possible, prevented. The attendants on the sick ought especially to take care that the ventilation of the sick-room is thorough, that cubic space is abundant, and that the utmost cleanliness is practised. Nurses must not hang over patients unnecessarily; they must also be careful to seal up and cover any wounds, no matter how trifling, they may have on their hands; they must go into the open air frequently, and not remain in the wards too many hours at a stretch; they must employ disinfectants freely on themselves and on the excreta of their patients, and use a disinfectant mouth-wash from time to time; they must be careful to wash hands and face before eating, and they must never partake of food or drink in the ward or sick-room. By carefully observing these common-sense precautions, the risk in nursing plague patients is very much reduced, and is certainly very much less than that attending the nursing of cases of typhus exanthematicus. To obviate risk from wounds and to prevent the access of fleas and similar suctorial insects, those engaged on plague duties should wear boots and have the legs protected by trousers tied tightly round the ankles or, better, by putties. Leather gloves are advisable if there is much handling of furniture or of anything likely to abrade the skin. Hospital work is only dangerous when patients are allowed to lie in their dirty flea-, louse-, or bug-infested clothing, when disinfectants are not properly used, and when attendants are careless, stupid, or rash, or where the wards, in the matter of light and ventilation, are by their construction ill adapted for plague cases, and where a number of pneumonic cases are crowded into a single apartment. Cats or dogs should not be allowed near plague patients.

The attendants on pneumonic cases should provide themselves with masks of muslin, three or four fold, and changed when at all damp, and also with goggles to protect the eyes. In Mukden a mask of ab[illegible]

cotton-wool (16 by 12 cm.) enclosed in muslin, and retained in position by a many-tailed gauze bandage, together with goggles, rubber gloves, and cotton uniform, proved thoroughly effective.

Haffkine's inoculations.—Early in the Bombay epidemic Haffkine introduced a system of prophylactic inoculation which is of proved value, both in reducing the number attacked with plague to the extent of from 77 to 85 per cent., and also in diminishing the mortality in those attacked by 80 per cent.*

It consists essentially in the subcutaneous injection of six-weeks-old cultures of plague bacilli incubated at 25°–30° C. and killed by heat—65° C. for one hour; carbolic acid, 0·5 per cent., is then added. The reaction is at times severe, but until quite recently no grave accident had occurred. The figures are not so favourable for Mauritius, where inoculations reduced the plague incidence to the extent of 45 per cent. only, and the mortality in those inoculated to 32·9 per cent. The Indian Plague Commission reports strongly in favour of these inoculations. All plague laboratory workers and all who are likely to be exposed to plague infection should receive them. The protection they confer lasts about twenty months. In the report of the Bombay Bacteriological Laboratory, 1911, Glen Liston states that in the inoculated the incidence of plague was 8 per 1,000 of the population concerned, whereas it was 34 per 1,000 in the uninoculated in the same communities; the case-mortality in the inoculated was 39·5 per 1,000 attacked, in the uninoculated 78 per 1,000. The best results were obtained from a two months' growth which had been stored about eighteen months. The prophylactic needs great care in its preparation. Its storage in hermetically sealed bottles should be insisted upon, and every bottle ought to be tested before use.

Lustig's injections.—Lustig and Galeotti have introduced a method of preventive inoculation which

* For a description of Haffkine's methods see *Brit. Med. Journ.*, June 12th, 1897.

apparently obviates many of the drawbacks of Haffkine's. They dissolve agar-agar plate cultures of *Bacillus pestis* in 1 per cent. solution of caustic potash, precipitate the nucleo-proteins so dissolved by weak acetic or hydrochloric acid, collect the precipitate, wash and dry it *in vacuo*. This substance, apparently, can be kept for an indefinite time. The dose for a man is about 3 mg. Before injecting it subcutaneously, it is dissolved in a convenient quantity of 0·5 per cent. solution of carbonate of soda. Its injection is followed by marked local and general reaction, and in the case of the lower animals by at least temporary immunity from plague. Favourable results have been obtained in man.

Klein advocated a prophylactic prepared by drying plague spleens at 47° C. over sulphuric acid. Ten to 15 mg. of this protects rats against virulent plague injections.

Strong prepared a vaccine by prolonged subcultivation of plague bacilli, or by cultivation on unfavourable media. Using the resulting living bacteria, he inoculated forty-two criminals. Beyond local and general reaction no harm ensued.

Other forms of antiplague vaccine have been introduced, but, so far, Haffkine's holds the field.

Treatment.—Hitherto the treatment of plague has been mainly symptomatic. In attempting to relieve symptoms the asthenic tendencies of the disease must ever be borne in mind, and depressant remedies of all kinds carefully avoided.

During the earlier stages, when headache and perhaps high fever are urgent, much relief may be obtained from ice-bags to the head and neck. If it be deemed advisable to attempt to lower the temperature, sponging of the body every hour with warm water is a much safer measure than the employment of such antipyretics as antipyrin and similar drugs. Vomiting, according to Lowson, is usually relieved by a full dose of calomel followed by a saline. If this does not succeed, or if diarrhœa be present, he recommends ice pills and an effervescing mixture containing morphia and hydrocyanic acid. Sinapisms

to the epigastrium are also useful. Later, when the pulse begins to fail, the same authority recommends strychnia, with or without carbonate of ammonia, in preference to digitalis or strophanthus. Strychnia, he says, should be used as a routine treatment, and commenced early in the disease. In collapse, stimulants of various kinds, including strong ammonia to the nostrils and ether hypodermically, are indicated; they sometimes succeed in resuscitating a sinking patient. Given with judgment, Lowson found that morphia was by far the best hypnotic. At the commencement $\frac{1}{8}$ to $\frac{1}{2}$ gr. hypodermically relieves suffering and procures sleep; later, $\frac{1}{8}$ gr. suffices. Hyoscine ($\frac{1}{200}$ to $\frac{1}{75}$ gr.) or chloral (20 gr.) and bromide of potassium (30 gr.) are of service for the same purpose. Diarrhœa, if urgent, is best treated by intestinal antiseptics, as salol in 10-gr. doses every four hours. The buboes in the early stage may be treated with applications of glycerine and belladonna. Should they become red and inflamed they must be poulticed and, on softening occurring, incised and dressed with iodoform. Indolent bubonic swellings should be treated with iodine liniment. Feeding and stimulation are to be conducted on ordinary principles. In the Manchurian epidemic intravenous injections of salvarsan were tried without effect.

Serum-therapy.—Yersin, Calmette, and Borrel have shown that intravenous, intraperitoneal, and subcutaneous injections of gelatin cultures of plague bacillus mixed with a little bouillon and heated for one hour to 58° C., if employed in doses just short of producing a fatal issue, and repeated three or four times at intervals of fifteen days, render rabbits immune to the plague bacillus. The heating kills the bacillus but does not destroy its toxins, which at first give rise to a very smart but, with each repetition of the injection, diminishing reaction. They further found that the serum of an immunized animal, if injected into an unprotected rabbit, exercised both an immunizing and a therapeutic influence. An unprotected rabbit was inoculated with a virulent culture of the bacillus, and twelve hours afterwards with

the serum. The progress of the disease, which would otherwise have certainly proved fatal, was at once arrested, and the animal recovered. They then immunized a horse by intravenous injections of living virulent cultures. After several injections made at intervals (the second after twenty days), they found that reaction, from being intense, became shorter and less pronounced, and that the serum of the animal was now both preventive and curative of inoculated plague in rabbits, guineapigs, and mice. At the Lister Institute an antimicrobic serum is prepared by injection of dead and afterwards of living bacilli into horses, and in which antitoxic bodies are produced as well by immunization against the nucleoproteins of *B. pestis*.

Accounts had led us to infer that the value of Yersin's discovery was practically established for man. Of 26 cases of plague in China treated with his antipest serum, 24 were reported to have recovered. Further experience in India, Hong Kong, and elsewhere has not confirmed these brilliant results, the serum treatment of plague both by Yersin's and by a number of other sera having so far proved a complete failure, and at the best but modifying the course of the disease and prolonging life.*

FLEAS

These minute ectoparasites are now of considerable importance to the student of Tropical Medicine in view of the part they play in the spread of plague, and probably of kala-azar as well.

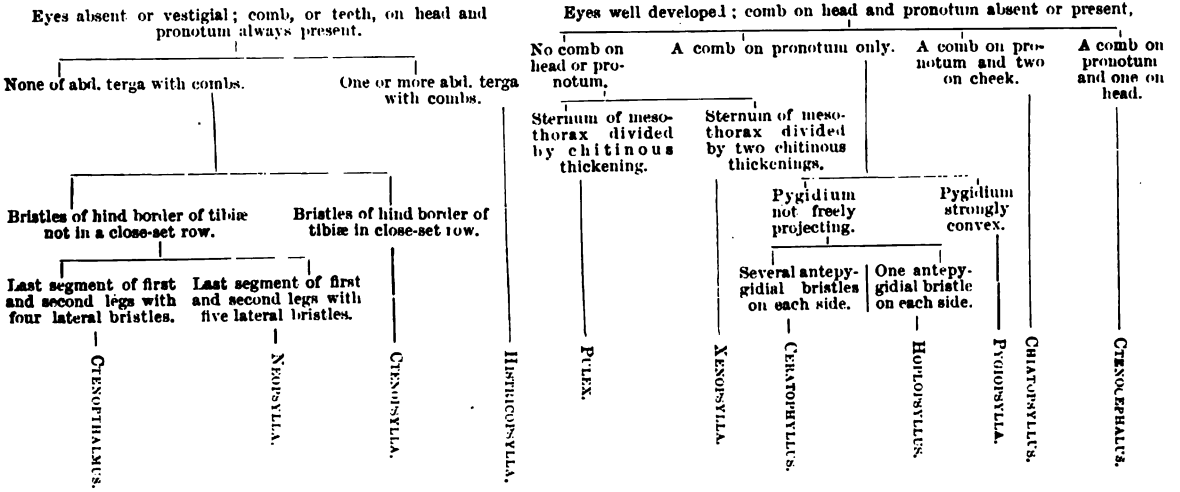
They are active parasites of mammals and birds; some suck blood indiscriminately, but the majority restrict themselves to one definite host.

In one family (*Sarcopsyllidæ*) the females eventually attach themselves to their host as fixed parasites, embedding themselves in its skin when pregnant; to this category belongs the "chigger."

The flea in its external structure is composed of a head, thorax, and abdomen.

* Connor (1913) has reported the apparent recovery of three patients to whom intravenous injections of iodine (1 part) and distilled water (60 parts) were frequently administered. If this be so, the method is worthy of further trial on a more extensive scale.

SYNOPSIS OF FLEAS.—I. FAMILY PULICIDÆ



II. FAMILY SARCOPSYLLIDÆ (DERMATOPHILIDÆ)

1. Hind coxa without a patch of spines on the inner side = *Dermatophyllus*. 2. Hind coxa with a patch of spines on the inner side = *Echidnophaga*.

The *head* is small compared with the abdomen, and is conical in shape; a comb of teeth is found sometimes on the cheek, or on the lower edge of the head. Eyes may be present or absent. The head is provided with short antennæ lodged in definite grooves. The mouth is furnished with appendages, maxillæ and palps, which conceal the other parts.

The *thorax* is composed of three segments, which are quite independent. Each consists of a dorsal arc carrying one or more belts of bristles. In some species the pronotum, or tergum of the first thoracic segment, carries a comb on its posterior edge.

The three pairs of legs are composed of a number of segments, the coxa being especially long and bread. The number and character of the bristles of the joints of the legs are used for distinguishing species.

The *abdomen* is composed of ten segments; on the ninth the tergum is in a great part occupied by a pitted sensory plate called the *pygidium*. In the male the sides of the tergum form large claspers. A large bristle or bristles project over and beyond the pygidium on the seventh segment, and are known as *antepygidial* bristles. There is a large and complex penis.

The female flea is larger than the male. The curved *receptaculum seminis* is a conspicuous object in the female.

The eggs are dropped by the female casually, and hatch in three or four days in summer time.

The larva lives in dust, is an active footless maggot, of a whitish colour, and is sparsely hairy. When full grown it spins a cocoon and pupates. The duration of the pupal stage depends on the temperature.

CHAPTER XX

UNDULANT FEVER

FEBRIS UNDULANS, MALTA FEVER, MEDITERRANEAN FEVER

Definition.—Undulant fever—a disease of low mortality, indefinite duration, and irregular course—is the result of infection by a specific germ, the *Micrococcus melitensis*. In its more typical form it is made up of a series of febrile attacks, each individual attack, after lasting one or more weeks, gradually subsiding into a period of absolute or relative apyrexia, also of uncertain duration. Common and characteristic complications are rheumatic-like affection of joints, profuse diaphoresis, anæmia, liability to orchitis and neuralgia.

Geographical distribution.—Undulant fever was somewhat unfortunately named Malta fever, for we now know that the disease which was so designated is not, as was formerly supposed, confined to Malta, or even to the Mediterranean. It is very common there, particularly in Malta and the eastern and southern littoral of the Mediterranean; but recent investigations show that it occurs in Italy, France, Spain, the Red Sea littoral, India, China, South Africa, Somaliland, West Africa, the West Indies, the Brazils, the United States, and even in England. I have seen two cases which originated in England; they gave the serum reaction. It is highly probable, therefore, that the same, or a similar, fever occurs in many other parts of the world, having been confounded hitherto with malarial fever or with typhoid. This conviction is based rather on clinical than on laboratory observation.

Experience has taught me to place little reliance on the serum-reaction test as ordinarily applied. Although with fresh blood and reliable cultures the reaction may be trust-

worthy, with stale blood and questionable cultures this test is most untrustworthy. Time after time, in London, I have got contradictory laboratory reports on blood from the same patients, presumed to have Malta fever. If the cultures in the London laboratories be so manifestly unreliable, it is probable that many of those in use in India and America are equally so, and that inferences as regards the geographical distribution of this disease, founded on the behaviour of these cultures with blood serum, are most untrustworthy. Lately, complement-fixation tests have given good results in Bassett-Smith's hands.

As it is extremely prevalent at times in the Mediterranean fleet and in the garrisons of Gibraltar and Malta, this disease is specially interesting to naval and military surgeons. Although only occasionally proving fatal, it is a fruitful source of inefficiency and invaliding.

Until recently it appeared to be on the increase in its old haunts, and to be becoming common in places where it was formerly rare—Port Said and Egypt, for example.

The following figures, supplied by Bassett-Smith, show its importance formerly to our Naval and Military Services in the Mediterranean:—

INCIDENCE OF UNDULANT FEVER

	Army			Navy			Total days' sickness.
	Strength.	Cases.	Deaths.	Strength.	Cases.	Deaths.	
1900	9,203	171	10	14,250	356	6	22,998
1901	9,384	288	10	14,070	286	3	16,987
1902	10,889	198	10	18,470	436	3	27,432
1903	10,608	507	11	18,410	400	6	30,541
1904	10,615	429	15	19,590	430	9	28,458

History.—Formerly undulant fever was confounded with typhoid and malaria. The labours of clinical observers from Marston (1861) to Maclean (1885), and more especially the bacteriological researches of Bruce (1887), Hughes, Gipps, Wright, Semple, and Bassett-Smith, have established it as a special disease. More recently an important advance of great practical value has been made by a Royal Society Commission, which has shown that the germ of this fever infests several of the lower animals, especially goats, in whose milk and urine it is excreted.

Etiology.—Bruce, in 1887, demonstrated the presence in the spleen in undulant fever of a special bacterium—the *Micrococcus melitensis*—and by a series of experiments proved that it was the cause of the disease. Unfortunately the bacterium occurs only sparsely in the general circulation (unless in the earlier stages, when the temperature is high), and therefore to search for it in the later stages of the disease does not aid in diagnosis; but pathologically Bruce's discovery is of great importance, as it enables us to say positively that undulant fever is a distinct disease, altogether different from either typhoid or malaria. The organism is present in abundance in the spleen pulp, and also in the lymphatic glands, in which it persists longer than elsewhere, and from both of which it can be separated by cultivation. Bruce found it in the spleen in ten fatal cases. His results have been confirmed by Hughes, Gipps, Wright, Durham, Bassett-Smith, and many others. Injections of pure cultures give rise to a similar disease in monkeys and other animals, from whose blood the micrococcus can be recovered, cultivated afresh, and, on injection into other animals, again give rise to the disease. In five recorded instances inoculation—intentional and accidental—of cultures of the micrococcus into man has been followed by the characteristic symptoms of undulant fever after an incubation period of from five to fifteen days.

The *Micrococcus melitensis* measures 0·33 μ in diameter. It occurs generally singly, often in pairs, sometimes in fours, but never, unless in culture, in longer chains. According to Gordon it possesses one to four flagella. It is readily stained by a watery solution of gentian violet, and is best cultivated in a 1½ per cent. very feebly alkaline peptonized agar beef jelly; in this medium, soon after inoculation, it appears as minute, clear, pearly specks. After thirty-six hours the cultures become a transparent amber; later they are opaque. No liquefaction occurs.

At one time believed to be a delicate organism, recent investigations have shown that the micro-

coccus can live for a long time in water, in dust, or on the clothes of patients, and that it is not killed by cold or desiccation. Moreover, it is now known that it is excreted in the urine, and that it occurs in great abundance in the milk and urine of apparently healthy goats (50 per cent.) and cows, and in the urine of apparently healthy men. It is also found in dogs (9 per cent.), sheep, and horses. These facts account in part for the great frequency and dissemination of the disease in such insanitary places as Malta, to which place they specially refer.

Influence of age and residence.—The most susceptible age is between the sixth and the thirtieth year. Length of residence does not influence susceptibility. In Malta the natives suffer as well as visitors.

Influence of season.—In Malta and other places where the disease is endemic this fever occasionally assumes an epidemic character. The period of its greatest prevalence in Malta is the season of lowest rainfall, embracing June, July, August, and September; differing in this respect from typhoid, which, in that island, is more prevalent during the succeeding months. It is not confined absolutely to the summer months; cases occur all the year round.

Local causes.—The disease tends to occur in particular towns or villages, in particular houses, barracks, hospitals and rooms, and in particular ships, manifestly originating in limited foci of infection. The weight of evidence was regarded by some as pointing to its diffusion by air currents, and not by food or water. There is no absolute certainty on these points. Evidence is rapidly accumulating to show that milk is the most important medium.

Formerly it was supposed that in Malta this fever was linked to the immediate neighbourhood of the seashore, and that the sewage-laden, tideless condition of the harbour at Valetta was somehow responsible for its prevalence there. Zammit has shown, however, that the disease occurs all over the island, and that in some instances it is more prevalent in certain inland and relatively sanitary villages than

in more insanitary towns and villages on the coast. Certain ships are notoriously foci of the disease, and, I believe, can carry the infection. Some time ago I saw a medical man suffering from a chronic fever whose blood, in expert hands, gave the characteristic reaction, and who, if he had undulant fever, certainly got it from a ship which had recently been to the Mediterranean. He himself had never been in that part of the world, and had not been out of England for a year.

Influence of social conditions.—All classes are liable to this disease; the officer and his family as well as the soldier in barracks or the sailor on shipboard.

Mode of infection. — Although the possibility must not be ignored, undulant fever is not generally transmitted directly from one person to another; that is to say, is not usually directly communicable from the sick to the healthy. The germ is readily conveyed by inoculation; the prick of a contaminated needle will suffice. Zammit and others seek to incriminate the mosquito as an inoculator, and point, in support of their contention, to the special prevalence of the disease in the mosquito season, to the facts that in 896 mosquitoes examined bacteriologically it was found in 4, and that the disease has twice been conveyed to monkeys by infected insects.

A very striking circumstance is that in some hospitals the nurses and attendants in the fever wards are ten times more liable to contract the disease than people not so employed.

Possibly the infection is blown about by winds as dust, and being inhaled, or falling into the conjunctival sac, or on a wound or sore, obtains an entrance. Bearing in mind the presence of the germ in the excreta of man and animals, the dusty character of the soil of Malta and many Mediterranean towns, the extremely minute dose of a culture required for a successful inoculation, in any or all of these ways infection seems possible. I have seen a case, originating in England, in which a father was apparently infected by placing in his mouth the clinical ther-

mometer used by his son recently invalided from Malta on account of the disease.

It is now known that the infection is conveyed in milk, and it has been suggested that it may be introduced in other kinds of food, or in water. Water as a usual medium may be dismissed, but there is strong evidence, judging from naval and military opinion, that, though the usual, milk is not the only medium. Facts point very distinctly to goat's milk as the most important medium of infection. In 10 per cent. of the milk of Maltese goats the micrococcus is present. Monkeys are easily infected by feeding them on such milk. Immediately on the goat's milk supply to the naval and military hospitals in Malta being stopped the cases of locally acquired undulant fever practically ceased. Formerly this fever was very common in Gibraltar. The milk supply of the garrison at that time was largely from goats imported from Malta. Gradually these goats have died out or been got rid of, and no more Maltese goats have been imported. Concurrently with this there has been a marked and proportional reduction of undulant fever cases in the garrison. In 1905 the s.s. *Joshua Nicholson* shipped 65 goats in Malta. An epidemic of undulant fever broke out on board, nearly all those who drank the milk of the goats being attacked.

Immunity.—Bruce holds that one attack confers immunity from subsequent attacks; other authorities believe that one attack, so far from conferring immunity, actually predisposes to subsequent attacks. The latter is Bassett-Smith's opinion, based on the fact that he finds the bactericidal power of the serum and the phagocytic energy of the leucocytes lowered during, and for some considerable time after, an attack of the disease.

Incubation period.—The period of incubation in the naturally acquired disease is difficult to fix. Cases have occurred as early as six days after arrival in Malta; on the other hand, the disease has shown itself as late as fourteen and seventeen days after the subject of it has quitted Malta. Some have held that it may remain latent for months.

Symptoms.—Undulant fever begins generally with lassitude and malaise, such as we associate with the incubation of many specific fevers, particularly typhoid. There are headache, boneache, anorexia, and so forth. At first the patient may go about his work as usual. Gradually the daily task becomes increasingly irksome, and he takes to bed. Headache may now become intense, and, in addition, the patient will suffer from thirst and constipation. At the commencement the symptoms, except that there is very rarely diarrhœa, resemble those of typhoid. There are no rose spots, however, then or at any subsequent period. There is evidence in the coated tongue, the congested pharynx, the anorexia, and the epigastric tenderness, of gastric catarrh; and the occasional cough and harsh, unsatisfactory breathing at the bases of the lungs indicate some degree of bronchitis or of pulmonary congestion. There may also be delirium at night. The fever is usually of a remittent type, the thermometer rising towards evening and falling during the night, the patient becoming bathed in a profuse perspiration towards morning. The spleen and the liver, but especially the former, are somewhat enlarged and, perhaps, tender. Lumbar pain may be urgent.

After a week or two of this type of fever, specially distinguished by pains and perspirations, the tongue begins to clean, and the appetite to revive; but, notwithstanding these signs of amendment, the patient still remains listless and liable to headache and constipation. He continues feverish and at times perspires profusely. Gradually, however, although the patient is anæmic and weak, subjective symptoms become less urgent; he sleeps well now, he has no delirium at night, and he can take his food, and this although the body temperature may still range slightly above the normal. Then once more, and perhaps over and over again, fever with all the former symptoms gradually returns; and now, if it has not declared itself before, the peculiar fleeting rheumatic-like affection of the joints or fasciæ, so characteristic of the dis-

ease, shows itself in a large proportion of cases. One day a knee is hot, swollen, and tender; next day this joint may be well, but another joint is affected; and so this metastatic, rheumatic-like condition may go on until nearly all the joints of the body have been involved one after the other. The patient may suffer also from neuralgia in different nerves—intercostal, sciatic, and so on. Orchitis is an occasional complication. In some cases these complications are severe and characteristic; in others they may be mild, or absent altogether. In this respect the same infinite variety exists as in other specific fevers.

Perhaps the most characteristic feature of undulant fever is the peculiar behaviour of the temperature. In a mild case there may be a gradual ladder-like rise through a week or ten days to 103° or 104° F., and then, through another week or so, a gradual ladder-like fall to normal, the fever, which is of a continued or slightly remitting type, leaving for good without complication of any sort in about three weeks. Such mild cases are the exception. Usually, after a few days of apyrexia, absolute or relative, the fever wakes up again and runs a similar course, the relapse being in its turn followed by an interval of apyrexia, which is again followed by another relapse; and so on during several months. This is the "undulant" type from which Hughes derived the name he suggested for the disease—*febris undulans.*

In another class of cases a continued fever persists for one, two, or more months, with or without the usual rheumatic, sudoral, and other concomitants—the "continued" type of Hughes.

Generally remittent or nearly continued in type, in a proportion of instances the fever exhibits distinct daily intermissions, the swinging temperature chart suggesting some septic invasion or a malarial fever. But there is no local evidence of suppuration to be found; neither, if we examine the blood, is the malaria parasite to be discovered; nor is the quotidian rise of temperature accompanied by any ague-like rigor, or at most only by a feeling

of chilliness; nor is the disease amenable in any way to quinine. This is the "intermittent" type of Hughes. In other instances these types may be variously blended.

In some patients, not months merely, but years, may elapse before they are finally rid of the tendency to febrile attacks and characteristic pains and aches. According to Bassett-Smith, the average duration of the disease is four months. Many of our sailors and soldiers are permanently invalided from the services on account of prolonged or recurring attacks of undulant fever.

Sequelæ and mortality.—As a rule, by far the most serious consequences of undulant fever are the debility it entails, the emaciation, the profound anæmia, the rheumatic-like pains, the neuralgias, and such sequelæ as abscess, orchitis, mastitis, parotitis, boils, etc. There is little risk to life; the mortality does not exceed 2·5 to 3 per cent.

When death occurs it is usually from suddenly developed hyperpyrexia; occasionally it is brought about by exhaustion, by hæmorrhages and purpuric conditions, or by some pulmonary complication such as pneumonia. In a few instances the fever is of a fulminating type, rapidly ending in death from hyperpyrexia. Hughes, in his elaborate monograph, designates such cases "malignant."

Pathological anatomy and pathology.—This disease has almost no pathological anatomy. The spleen is the only viscus of which it can be said that it is distinctly diseased. In undulant fever this organ is enlarged (average 17 oz.), soft, and diffluent; on microscopical examination the lymphoid cells are found to be increased in number. There may be some congestion and even ulceration of the intestinal mucosa, but this is not an essential feature.

Diagnosis.—The diagnosis of undulant fever from typhoid is an important practical matter. It is exceedingly difficult in the early stages. Principal reliance has to be placed on the presence or absence of rose spots, of diarrhœa, of joint-com-

plications, of sweats, the locality where and the season in which the disease was contracted, and, if available, the agglutination and precipitation tests.

According to Nicolle, there is a mononuclear increase, 70-80 per cent.; apart from this, microscopical blood examination, unless in a negative sense, is of no value in diagnosis.

Wright has shown that, both as regards sedimentation and agglutination, the germ of undulant fever reacts to the serum test in the same way as, and even more markedly than, *Bacillus typhosus*. A weaker dilution (never less than 1 in 30 or 50) than in typhoid must be used. Dead cultures give the reaction, and can be conveniently kept in stock for diagnostic purposes; they are grown on agar, washed off with sterile normal saline, killed by heat at 60° C. or by formalin vapour. These observations have been abundantly confirmed. The agglutination reaction appears early in undulant fever as compared with typhoid, being available for diagnostic purposes by the end of the first week of the fever. It persists long after convalescence, often for years.

The unreliability of the serum test for undulant fever is in part explained by the researches of Nègre and Raynaud, who found that certain strains of *M. melitensis* agglutinated with normal sera, whereas other strains did not agglutinate with undoubted undulant-fever sera. The latter they name the "paramelitensis group." Bassett-Smith concurs in this. Therefore, before concluding from a negative reaction that any given case is not undulant fever, the serum should be tested with a paramelitensis culture.

After the fever has gone on for several weeks diagnosis is, of course, easier; in the early stages, on clinical grounds alone, and apart from the agglutination test, it may be almost impossible. It may be that it is only on the post-mortem table that we have the relative assurance, from the absence of ulceration in the ileum, that we have had to deal with a case of undulant fever. Cultures from spleen pulp, with subsequent inoculation into animals, should give reliable evidence if the results are positive. Tuberculosis,

abscess, empyema, malaria, relapsing fever, and all the causes of continued high temperature of a septic type have to be carefully excluded in attempting a diagnosis. The possibility of the concurrence of another infection, typhoid for example, must not be overlooked.

Prognosis.—In the present state of our knowledge it is impossible to say how long any given case of this disease may last, what the risk to life may be, or what complications may be encountered. Birt and Lamb, from a series of valuable observations, conclude that important deductions may be derived from the behaviour of the agglutinating substances present in the blood. Their conclusions are, briefly, as follow: (1) Prognosis is unfavourable if the agglutinating reaction is persistently low; (2) also if the agglutinating reaction rapidly fall from a high figure to almost zero. (3) A persistently high and rising agglutinating reaction sustained into convalescence is favourable. (4) A long illness may be anticipated if the agglutination figure, at first high, decreases considerably. These conclusions are borne out by Bassett-Smith's very careful work.

Treatment.—Malta and those Mediterranean ports in which this fever is endemic should be avoided by pleasure- and health-seekers during the summer. Those who are obliged to live there all the year round would do well, at this season, to leave the towns and reside in places of healthy repute in the country. As a matter of precaution, in the endemic area the drinking-water, food, and drains ought at all seasons to receive special attention. *All milk should be avoided, or sterilized by boiling*, and food dishes should be washed with boiled water. Every care should be taken to avoid insect bites and other skin lesions. Laboratory workers must be careful in handling cultures of the micrococcus; the accidental introduction of the micrococcus into the conjunctival sac has sufficed to cause the disease.

When the diagnosis is sure, it is well to give a purge—none better than calomel and jalap—and to instruct the attendants to keep the patient's tem-

perature systematically below 103° F. by cold sponging with vinegar and water or, if necessary, by cold bath or ice variously applied. In view of the prolonged nature of the fever, this measure is one of importance; at the same time, such treatment need not be applied too energetically, or so as to depress; a fall of 2° or 3° is all that is desirable.

Bassett-Smith recommends yeast and its products. Quinine and, on account of the joint affection, the salicylates are very generally prescribed. Both are useless, if not injurious. Phenacetin and similar antipyretics are also often given to bring down temperature; but the wisdom of employing depressing drugs in so chronic and asthenic a disease as undulant fever is, to say the least, questionable. Any threat of hyperpyrexia is best met as directed, namely, by early employment of sponging, the wet pack, or, if necessary, by the cold bath. Sleeplessness may demand hypnotics; headache, if severe, moderate doses of phenacetin, pyramidon, or similar drug; inflamed joints or testes, the usual local applications; constipation, enemata or aperients. In fact, the treatment of undulant fever resolves itself into a treatment of symptoms.

The therapeutic employment of vaccines of dead *M. melitensis*, prepared and administered according to Wright's methods, has been favourably reported on by Reid. In Bassett-Smith's hands the results have not been so favourable. After a prolonged and very careful trial, the latter concludes that if used during the acute phases of the fever, so far from doing good, they act detrimentally, but that in chronic cases, with slight relapses and low temperatures, by stimulating slightly the machinery of resistance they are of real value, and it is to this type of case that he now restricts their use. Sergent concludes that the practical value of serum-therapy and vaccination in undulant fever has not been demonstrated.

The *diet* at first should consist of milk (in Malta boiled); later, of broths and eggs and, if necessary, stimulants. Solids must not be freely given during

high fever or when the tongue is coated. If appetite is present ordinary simple food may be taken. Lemonade or lime juice should be given after a time; not merely as a pleasant, thirst-relieving beverage, but with a view to averting scurvy—not at all an improbable complication if the diet is too restricted over a long period. Feeding must be conducted with the greatest circumspection, avoiding overfeeding on the one hand, and a low monotonous diet on the other. The tongue and the appetite are the best guides.

Exercise, travelling, and anything that tends to induce fatigue are prone to provoke relapse if indulged in prematurely; but a couch or chair in the garden is to be encouraged, weather permitting. The patient should rest for at least three weeks after temperature has become normal.

Flannel clothing should be worn, and frequently changed if there is much sweating.

Change of climate is not so necessary as in malarial affections, seeing that the disease may persist in England, and that it may gradually wear out in the endemic localities. It is not desirable to move a patient when fever runs high, or when debility is very great, or when the cool and healthy season in the Mediterranean is at hand. It must be considered that at this time winter is approaching in England, with climatic conditions very unsuitable for a patient who has become anæmic and debilitated from a long course of fever; at this season he would do much better in a milder climate. When, however, the case occurs early in the summer, or runs over the winter, then, in order to avoid the heat of the Mediterranean, change to England, if feasible and if it can be comfortably effected, should be advised.

When possible the subject of undulant fever would do well to avoid the endemic area for one or more years after recovery.

Prevention.—Though mules, asses, oxen, cows, rabbits, and fowls can convey the micrococcus, there is no longer any doubt that goat's milk is the principal medium through which undulant fever is com-

municated to man.* This discovery has led to very striking and important results.

On the recommendation of the Mediterranean Fever Commission, the use of the milk of the Maltese goat was interdicted in the naval and military forces of that island. Immediately the incidence of undulant fever began to drop in the Navy from an average of 240 per annum up to 1906, to 3 in 1910, and in the Army from a previous average of 315 per annum to 9 in 1907. In 1909 the health authorities in Malta were authorized to kill all goats whose blood or milk gave the *M. melitensis* reaction. The goat population of the island was consequently reduced from 17,110 in 1907, to 7,619 in 1910. Concurrently the fever incidence in the civil population fell from an annual average of 632 to 318 (Eyre).

These facts suffice to indicate the direction preventive measures should take. It must be borne in mind that certain products of milk—cheese, butter, etc.—may communicate the germ, and, further, that infected goats may appear to be in perfect health and may milk satisfactorily.†

* Proportion of infected goats in—

Malta	50 per cent.
Algeria	3·4 ,,
Tunis	30·7 ,,
Marseilles	34·2 ,,

According to Zammit, samples of infected milk are now being detected by the health authorities at Malta by employing the diluted milk for agglutinating cultures of *M. melitensis* macroscopically in capillary tubes; the result being subsequently confirmed by a positive reaction of the serum of the suspected goat, which is then destroyed. This method is said to give rapid and reliable results, in addition to being more convenient than the agglutination reaction with serum alone.

† It would seem that in South Africa infected goats often have marked arthritic symptoms, may suffer from mammitis, and are prone to abort.

CHAPTER XXI

TYPHOID FEVER IN THE TROPICS, AND TYPHO-MALARIAL FEVER

Typhoid Fever

The existence of typhoid fever in the tropics was for long not only ignored but actually denied, even by physicians and pathologists of repute. Formerly, the idea of malaria so dominated all views of tropical fevers that nearly every case of pyrexia, other than those of the most ephemeral description, or those associated with the exanthemata or with manifest inflammation, was relegated to this cause. When ulceration of the ileum was encountered post mortem the lesion was regarded, not as the specific lesion of the fever, but merely as a complication. More correct views prevail at the present day, and typhoid now ranks not only as a common disease in the tropics, but, to the European there, as one of the most commonly fatal. Little is known about typhoid as a disease of natives; Rogers has shown that in Calcutta, at all events, it is by no means uncommon among all classes. As a disease of Europeans it is only too familiar to the army surgeon in India and to the civil practitioner in most if not in all parts of the tropical world.

Besides being the scourge of the young European in India, typhoid is common enough in Japan, in China, in Cochin China, in the Philippines, in the Malay country, in Mauritius; the French have had large experience of it in Algeria and their West African possessions; the British have had similar experience in South Africa. It is also found in the West Indies; in Nigeria even; in fact, wherever it has been properly looked for.

Typhoid fever is, one might almost say, alarmingly prevalent among young soldiers and civilians in the East. It is very common among them during the first two or three years after their arrival. Fortunately, the liability decreases with length of residence. Apparently a sort of acclimatization, or rather habituation, to the poison is established with time, just as tends to be the case with other organic poisons. It is not unlikely that the relative exemption—if such there be—of the native races is owing to a like immunizing effect produced by living in constant contact with typhoid and similar toxic agents, or to an attack in childhood. On visiting native cities—Chinese cities, for example—one is filled with amazement at the state of filth in which the people live, and not only live but thrive. The streets are narrow and never cleansed ; the common sewer lies beneath the flagstones, and through the interstices between the stones can be seen the black, stinking slush in the sewer. The sewage is not confined in a well-laid cemented drain, but soaks through the loosely laid, uncemented stones, and thoroughly saturates the ground on which the tumble-down, overcrowded houses are built. Night soil is allowed to remain in wooden buckets inside the houses awaiting collection by the soil merchant, who sells it to the market gardener and the farmer. Urine is accumulated in earthenware jars, and is similarly disposed of. The houses are rarely swept and cleaned, hardly ever repaired. In every corner are filth and rubbish. And yet, in such circumstances—in which the sanitarian would prophesy typhus and typhoid—the population seems to thrive. Doubtless, where the European would almost surely contract typhoid and other filth diseases, the natives have obtained an immunity.

In Eastern countries little or no care is taken to prevent contamination of the wells and streams with sewage matter, and unless foreigners are very careful about boiling their drinking-water and the water in which their plates, etc., are washed, avoiding salads and all uncooked vegetable dishes, refraining from bazaar-made drinks, and protecting their food and

food dishes from flies and other mechanical transmitters of the *Bacillus typhosus*, they are almost sure, sooner or later, to fall victims.

It would appear that typhoid is not only a common disease among Europeans in the tropics, but that it is also a very virulent one, with a death-rate twice as heavy as the death-rate of typhoid in England. According to my experience in China, not only is the tropical form grave from the outset, but it is extremely liable to relapse. In England the death-rate is put down at about 1 in 8 attacked; but in India the elaborate and carefully prepared statistics show a death-rate of rather over 1 in 3. What with its frequency and its high rate of mortality, typhoid in India kills more European soldiers than does cholera.

Not only does typhoid exhibit increased virulence, but experience has shown that against it those sanitary safeguards which are found to be practically sufficient in England are by no means so effective in India. It would also appear that soldiers on the march contract the disease in passing through uninhabited country, in spite of the fact that the camp may be pitched in spots which, presumably, had never been occupied by man before, and although the men may have drunk only of water from springs and streams that were beyond suspicion of fæcal contamination. Similar testimony comes from Australia, where typhoid has occurred in the back country in lonely spots hundreds of miles from fixed human habitations. From these data the inference is suggested that Eberth's bacillus, under certain conditions of soil and temperature, may exist as a pure yet virulent saprophyte, for which an occasional passage through the human body is by no means necessary.

Anti-typhoid inoculation.—Having observed that injection into the subcutaneous tissues of the human subject of dead cultures of *Bacillus typhosus* conferred on the blood of the individual experimented on the power of agglutinating and sedimenting living cultures of the bacillus, Sir A. Wright, in the hope that in this circumstance he had grounds for conclud-

ing that protection against typhoid might be conferred by some system of artificial immunization, devised such a system, and has practised it on a scale sufficiently extensive to warrant some conclusions.

During the Maidstone epidemic of typhoid in 1897, of 200 individuals, the subjects of special observation, 95 were inoculated, 105 were not inoculated. None of the former contracted typhoid, whereas 19 of the latter were attacked. Encouraged by these results, Wright proceeded to inoculate on a larger scale. In the *British Medical Journal* of January 20, 1900, he summarizes his results up to that date. Of 11,295 British soldiers in India, to whom his observations apply, 2,835 were inoculated, 8,460 remained uninoculated. Of the former, 27 at some subsequent time had attacks of naturally acquired typhoid; of the latter, 213 were similarly attacked; the percentages being 0·95 and 2·5 respectively. In these attacks 5 of the previously inoculated died; 23 of the uninoculated. On the assumption that the whole of the British army in India was inoculated and that the foregoing results were maintained, there would be an annual saving of over 1,000 cases of enteric and of nearly 200 lives.

Since that time Sir A. Wright, with an industry and zeal in keeping with the important stake at issue, has steadily pursued his investigations. The English garrison in Egypt and the South African War afforded opportunities to test his conclusions in other fields, and on an extensive scale. The figures appear to justify the conclusion that these inoculations lead to at least a twofold reduction in the incidence of the disease in those inoculated, and a 50 per cent. reduction of the case-mortality. Crombie concluded from a careful and independent examination of the statistics, based on the results of inoculation as against non-inoculation in a group of 250 officers invalided from various causes from the South African War, that up to the age of 30 the advantage of a single inoculation is distinct—27 per cent. of the inoculated being attacked, as against 51 per cent. of the non-inoculated. Beyond 30 he fo

the positions reversed, the advantage being with the non-inoculated. The results were better after a single than after a double inoculation, which appeared, according to Crombie's figures, to increase the liability to infection.

Since the time Crombie's statistics were compiled anti-typhoid inoculation has been extensively practised not only in the army in India, but also by the French in their armies in Tunis, Algeria, and Morocco, and by the Americans on the Mexican boundary, with gratifying results. Better methods of preparation and dosage have been introduced, and the reaction after vaccination has been mitigated thereby, so that fewer object to the operation, which in healthy people is free from danger. According to Leishman, the rule is to use a vaccine not over three months old, to give two doses, the first containing 500 million bacilli, and ten days later the second of 1,000 million bacilli. The average duration of protection he considers to be two years, after which one injection of 1,000 bacilli should be given.

Full details of the method of preparation and of the clinical effects of Sir A. Wright's inoculations will be found in the *Lancet* of September 19, 1896, and the *British Medical Journal* of January 20, 1900.

It is not requisite to enter further into the subject of typhoid fever, for although this important disease is abundantly common in the tropics, it is not properly classifiable as a tropical disease; moreover, it is fully dealt with in every textbook on general medicine. It is alluded to here rather by way of warning the practitioner in the tropics against overlooking it, and against assuming that every case of fever he may encounter is malarial; and, also, of indicating the special importance to him of a knowledge of the latest views on the practical value of anti-typhoid inoculation.

Typho-Malarial Fever

Some years ago a good deal was said, particularly in America, about "typho-malarial fever." An idea got abroad that there is a specific disease which,

though resembling both, is neither typhoid nor malarial, nor any of the other recognized forms of continued fever. There is no doubt that in warm climates, besides the known fevers, there are several, if not many, undifferentiated specific fevers. But the clinical group indicated by the term "typho-malarial" is not one of these. Typho-malarial fever is an ordinary typhoid occurring in a person who has been exposed to malarial influences, i.e. who has become infected with the malaria parasite.

It has already been pointed out that the malaria germ may remain dormant for months or even years in the body, and then, on the occurrence of severe physiological strain—such as a chill, shock, excessive fatigue, and so forth—wake up again, and once more multiply and flourish in the blood and give rise to the phenomena of malarial fever. It is a recognized clinical fact, one familiar to our predecessors and much insisted on by them, that any disease process occurring in a person who has once had malarial fever is prone to take on an intermittent or periodic character; as if the previous malarial infection had left a sort of impress of periodicity on the constitution. Doubtless this is owing to the fact that in individuals with Laveran's parasite dormant in their tissues the physiological strain implied by the presence of active disease paralyses for the time being the innate protective power of the human body, and the parasite is once more permitted to multiply and work its mischief in the blood. There are few more depressing influences than typhoid. Little wonder, then, that typhoid in a malarial is often accompanied by clinical evidences of a resuscitation of the malaria germ. And so it comes to pass that an attack of typhoid in malarial countries, or in persons returned from malarial countries, is prone to assume some of the characters of intermittent or remittent fever.

Not infrequently, instead of the slowly increasing headache, malaise, creeping cold, anorexia, and day-by-day ladder-like rise of temperature, the first recognized sign of typhoid in such circumstances is a violent rigor,

immediately followed by rapid rise of temperature, which, in an hour or two, mounts to 104° or 105° F., to be succeeded in a few hours by profuse sweating and a partial remission of fever exactly resembling an attack of ague. For the next two or three days these attacks are repeated, the remission becoming less complete each time. Quinine may be given; but, although the rigors and marked oscillations of temperature are checked, the practitioner is surprised and disappointed to find that the temperature keeps permanently too high, and that the typhoid state is gradually developed. Or it may be that a typhoid fever begins in the usual insidious way, runs its usual course for a week or two, and then, in the middle of what is regarded as an ordinary typhoid, rigors and temperature oscillations and other malarial manifestations show themselves. If quinine is given these oscillations cease and the typhoid resumes its usual course. Or it may be that it is not until the end of the fever and during convalescence that these malarial symptoms are developed. Several such cases are now on record in which the malaria parasite was found in the blood.

The **diagnosis** between typhoid and some forms of malarial remittent is often exceedingly difficult, in certain cases almost impossible, without the assistance of the microscope and the serum test. The principal points to be kept in view are, first, the mode of incidence of the disease. In typhoid there is a gradual rise of temperature, a daily gain of a degree or so during several days, the maximum not being attained for five or six days; as against the sharp rigor and sudden rise of temperature through five or six degrees in the first few hours in malarial fever. Secondly, the characters of the gastric symptoms differ. Thus, in malarial remittent there are bilious vomiting and perhaps bilious diarrhœa, tenderness of the liver, epigastrium, and spleen, and an icteric tint of skin and scleræ; in contrast to the abdominal distension, perhaps the iliac tenderness and gurgling, and the peasoup stools of typhoid. Such signs as epistaxis, deafness, and cheek-flushing in typhoid have a certain weight, but skin eruptions in the tropics are of little aid in the

diagnosis of such cases. Prickly heat, or its remains, is present in nearly everyone, sick and healthy, malarial or typhoid patient alike; so that rose spots are to be found in nearly all fevers in hot weather. None of these signs can be considered as absolutely diagnostic; all or any of them may be present in typhoid, and all or any of them may be present in malarial remittent. The only really diagnostic marks are tertian or quartan periodicity, amenability to quinine, and, above all, that supplied by the malaria parasite in the blood and the Widal serum test. In all doubtful cases the malaria parasite should be sought for; if it is found, the case has certainly a malarial element, and quinine is indicated. If it is not found, and if quinine has not been administered and several negative examinations of the blood have been made, the case is probably one of pure typhoid. Nevertheless, if the malaria parasite is found, typhoid is not necessarily excluded.

No one who is proceeding to the tropics to practise medicine should fail to familiarize himself with the technique for the Widal reaction. In Europe he can fall back on the bacteriologist; in the tropics, as a rule, he cannot do this.

Prognosis and management.—Remittents under suitable treatment we expect to see recover; typhoids too often go the other way. A word of caution may be given as to prognosis and treatment. In forming diagnosis too much weight must not be attached to the presence or absence of diarrhœa; constipation is much more common in tropical typhoid than in the disease in Europe. Diagnosis, therefore, must not be too much influenced by absence of diarrhœa, and the practitioner must not be led by the presence of constipation into giving active purgatives. Purgatives are often of the greatest service in malarial remittent; but if, in consequence of a mistake in diagnosis, it is assumed that a case of typhoid is remittent, and large doses of calomel and other cathartics are administered, the result may be disastrous. If doubt exist about diagnosis, and quinine be given, it will not do a typhoid much harm. It is a good rule, therefore, when in doubt, to give quinine, but to avoid purgatives.

CHAPTER XXII

IMPERFECTLY DIFFERENTIATED FEVERS OF THE TROPICS

THERE can be little doubt that in the tropics there are a number of fevers specifically distinct from any of the foregoing, and also from the better-known fevers of temperate climates. Such fevers are constantly met with and are a perpetual puzzle to the conscientious diagnostician; and, up to the present, little of a truly scientific character has been done towards describing, separating, and classifying them. Some attempts have been made to arrange these imperfectly differentiated fevers on a clinical basis; but, until their causes have been discovered and, above all, until they have been studied in reference to any possible connection they may have with the known pathogenic tropical parasites, anything like a sound classification and description has to be postponed. So far as known, they are not associated with distinctive exanthems or even with distinctive visceral lesions; a circumstance which has contributed, doubtless, to retard our knowledge in a very important department of tropical medicine.

The late Colonel Crombie, I.M.S., attempted a classification of these fevers on a clinical basis, which, so far as it goes, is of distinct value. His remarks apply solely to the fevers of India; but I can recognize in his descriptions clinical forms which I frequently met with formerly in China. It is fair to infer from this latter circumstance that, if these fevers are found in India and China, they probably occur also in other warm countries.

Crombie divided them into **simple continued fever, low fever,** and **non-malarial remittent.** To these I would add yet another, which, from experience in China, I regard as a distinct

clinical entity, and which from its peculiar feature I would call **double continued fever.**

Since Crombie wrote, several observers have made important contributions to the subject, notably Thompstone and Bennett, who described under the name of hyperpyrexial fever what appears to be a special form of fever in West Africa; McCarrison, who has described a fever of three days' duration occurring in Chitral (p. 380), and which may be phlebotomus fever; and Rogers, who has more recently described one of seven days' duration in Calcutta (p. 382).

Simple continued fever.—Simple continued fever generally, if not invariably, commences with a rigor, the temperature rapidly or more slowly mounting to 104°, 105°, or even 106° F. There are headache, malaise, a white furred tongue, anorexia, thirst, and perhaps vomiting. The fever lasts usually from three to eight days; occasionally it is prolonged for two, three, or four weeks. Crombie remarked that these cases are particularly common in towns, and were known locally as Bombay fever, Calcutta fever, and so forth. It might be suggested that such fevers are mild or aborted typhoid; but, in view of the absence of the characteristics of enteric, the insignificant mortality, and the freedom from complications, so grave a diagnosis does not seem to be justified. It is customary to attribute them to heat, chills, change of season, acclimatization, irregularities in diet, exposure to the sun, and the like. How far these etiological speculations are correct it is hard to say.

Low fever.—Like the preceding, this type of fever is not an unusual one among Europeans in the tropics. Its characteristics are indefinite duration—weeks or months; a persistent though slight rise of temperature, rarely above 101·5° F. but never below 99°; anorexia, debility, loss of flesh, and a tendency to bilious diarrhœa. It is unrelieved by quinine or arsenic; but it almost invariably responds to a change of air, especially to a trip at sea.

Non-malarial remittent.—Crombie remarked that it is a pity we have no better name for this fever, which is of very frequent occurrence in India, and is

one of the most fatal of the fevers there. Remittent is a misnomer, for the symptoms are even less remitting than those of typhoid. The temperature runs high, touching 104° or 105° F. for a long part of its course. It begins not unlike simple continued fever. By some it is considered a variety of typhoid, notwithstanding the absence of many of the symptoms of that disease. Hepatic enlargement and congestion are early and constant conditions; but the spleen, as a rule, is not distinctly enlarged.

"Bilious diarrhœa, in no respect resembling the diarrhœa of typhoid, is also a very frequent symptom. Quinine—often given in large and repeated doses in these cases—is not only not useful, but so obviously adds to the distress of the patient, without in any way producing an improvement in the progress of the symptoms, that it is very soon abandoned. Meanwhile, the temperature continuing persistently high, marked head symptoms, especially delirium of a muttering and irritable kind, come on, and the patient may even, and often does, pass into a condition of coma from which he can hardly be roused. This condition of persistent high temperature without marked remission, a distinctly enlarged and congested liver, bilious diarrhœa, congestion of the back of both lungs, and a low, muttering delirium, is generally reached by the eighteenth to the twenty-fourth day. If coma supervenes, the patient frequently dies about this period. In more favourable cases, where the symptoms are less severe, they may continue for a week or two longer. In such the average duration of the case is six weeks."—(Crombie.)

Crombie, although he had seen this fever in Europeans, regarded it as being essentially a disease of natives. It is seldom met with after the age of 30, but is frequent enough in childhood.

Double continued fever.—In South China I encountered, both in Amoy and in Hong Kong, a peculiar type of fever, apparently of very little gravity as affecting life, but sufficiently distressing while it lasted. Thorpe has recorded a case occurring in Wei-hai-wei. The disease is characterized

by an initial pyrexial stage of from ten days' to a fortnight's duration, followed by a stage of from three to seven days' relative or absolute apyrexia, which, in its turn, is succeeded by another spell of about ten days' duration of smart fever and then by convalescence (*see* Chart 6). Both in the primary and the terminal fever the evening temperature may rise to 104° or 104·5° F. It might be said that such cases are relapses of simple continued fever; but as I have seen, on at least two occasions, the same succession of events occurring almost simultaneously in two patients living in the same house—once in husband and wife, and once in brother and sister — it seems probable that this is a special form of disease, and that the double fever is a constant and characteristic feature. In the case of the brother and sister the march of their fevers was strictly simultaneous, the primary

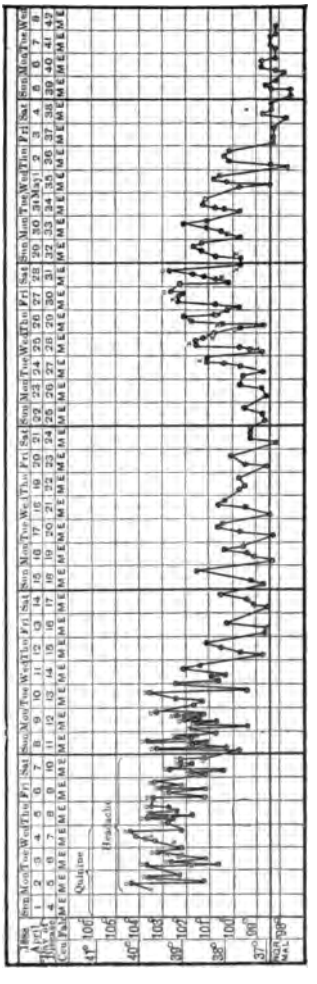


Chart 6.—Double continued fever, Hong Kong. o indicates a dose of antipyrin.

fever, the apyretic interval, and the terminal fever occurring in both patients on the same days. Beyond a certain amount of headache and febrile distress there are no special symptoms, so far as I have been able to observe, nor any special complications.

The three-days' fever of Chitral. *Definition.* — "An acute infectious disease, epidemic in the Chitral Valley during the summer months, and characterized by a single paroxysm of fever of typical course, which persists for about three days, without marked local affection. The paroxysm is accompanied by severe headache, pain in the back, bones, joints, and muscles, and is followed by severe prostration, which continues for ten days or more after the attack."

Under the above title and definition McCarrison has described * a well-defined type of fever annually prevalent in Chitral from April to July, and affecting more especially young natives and new-comers. So far, the disease has not been associated etiologically with a micro-organism. Apparently it is not directly contagious, being acquirable in certain infected localities only; a circumstance suggestive of an animal intermediary.

In most instances one attack confers immunity, at all events during a current epidemic; second attacks occur in 5 per cent., and third attacks in 1 per cent. only. McCarrison brings forward evidence to show that, in the Chitral garrison, Europeans and Goorkhas were much more susceptible than Hindustanis. This relative immunity of the Hindu he regards not as racial, but as having been acquired from previous attacks of the disease in the plains of India. If this be the correct interpretation of the relative freedom of the Hindustani in Chitral, we must conclude that three-days' fever is common and endemic in India, and that it is more or less of an exotic in Chitral, where it can develop only when the atmospheric temperature reaches 75° F., or the temperature demanded by the hypothetical animal intermediary (McCarrison suggests the sand-fly)

* *Ind. Med. Gaz.*, Jan., 1906.

subserving the germ. Possibly what used to be described and regarded as the fever of acclimatization in India is this three-days' fever. (*See* Phlebotomus Fever, p. 281.)

Symptoms.—After an incubation period of from one to six days, with or without a prodromal stage, the fever is ushered in by slight or more severe rigor. The face becomes flushed, headache is intense, and there is usually severe general aching. In from twenty-four to thirty-six hours the temperature has reached 103–4° F. It keeps about this point for a day longer, and then begins to fall, with or without epistaxis, vomiting, sweating, or diarrhœa, reaching the normal about the end of the third or beginning of the fourth day. The patient continues debilitated, especially mentally, for a week or two longer.

Serious complications do not occur, but in some years diarrhœa, in other years pharyngitis, are features of the epidemic.

There are no important sequelæ. Desquamation is very rare; a point which, together with the absence of an eruption, serves to differentiate this fever from dengue, a disease resembling it in many respects. The mortality is nil in the healthy.

Treatment.—There is no specific known for this disease. Treatment must therefore be conducted on general principles.

As it would appear that three-days' fever is a disease of locality, houses and places believed to be infected should be avoided, and, where possible, disinfected.

Hyperpyrexial fever.—From time to time we have accounts from the West Coast of Africa, where it is not uncommon in certain parts, of a peculiar type of fever, especially prevalent during the dry season, and which doubtless was formerly regarded and treated as malarial, but which, from the absence of the malaria parasite in the blood, and the impotence of quinine in checking it, we now know cannot be malarial. From its gradual incidence and prolonged course, although it is associated with hyperpyrexia, we know that it

cannot be siriasis or heat apoplexy. What it may be is difficult to say; the probabilities seem to be in favour of its being a special form of tropical disease, associated with an animal intermediary occurring in and limited to the endemic localities.

Symptoms.—Thompstone and Bennett describe the clinical features thus: "This fever is generally ushered in by a slight rise of temperature, followed by profuse perspiration and a fall in the temperature to about 99° F. After a period of apyrexia of perhaps twenty-four hours' duration, the temperature begins again to rise, slowly at first, but when 105° is passed, with alarming rapidity, one degree in ten minutes having been frequently observed, and it may reach 107 on the second day. For fourteen or even for thirty days subsequently there is absolutely no tendency for it to fall. The skin acts either very slightly or not at all, and all antipyretic drugs fail."

In due course the tongue becomes dry and shrivelled, but the spleen and liver are not enlarged; the urine is normal and abundant, the bowels being regular or loose. The conjunctivæ are injected, the pupils contracted. There is much anxiety and restlessness; but the mind is clear in most cases except when the temperature is very high.

If the patient is to recover, a change for the better may be looked for about the end of the third week. Convalescence is very gradual, and it may be six weeks before temperature is normal. Half the cases die.

A curious feature is the remarkable rapidity with which the blood coagulates the moment it is exposed to the air.

Malaria parasites, though carefully sought for, have not been found; neither have attempts at cultivations from the blood yielded any micro-organism. The white corpuscles are rather in excess.

Treatment.—The only treatment which has been of value is the diligent use of the cold bath and the cold pack.

Seven-days' fever of Indian ports. *Definition.*—A short fever occurring epidemically during

the summer months in Indian ports, and characterized by sudden invasion, severe headache, pains in the back and limbs, and pyrexia of a peculiar saddle-back type—occasionally of a continued type—lasting from six to seven days and associated with a pulse which is relatively slow in relation to temperature.

History.—Possibly this fever is one of several fevers included under the somewhat comprehensive term "simple continued fever." Rogers, by a careful study of a vast number of cases of fever in Calcutta, observing that this particular type has a definite seasonal incidence—the late hot weather and the early monsoon months in Calcutta, and declines just at the time when the principal malarial rise of the year takes place—concludes from this and from the absence of malarial parasites that it cannot be malarial, from the absence of respiratory symptoms that it is not influenza, and from the absence of violent joint pains and eruption that it cannot be dengue. He cultivated a bacillus from the blood, but did not succeed in establishing any causal relationship of the organism to the disease. He further states that it usually begins amongst the sailors and spreads later to the townspeople; that it occurs in other Indian ports, but is probably unknown in the interior of the country. Apparently it is a mild disease, has no mortality, and no distinctive pathological anatomy.

Diagnosis of imperfectly differentiated fevers.—The diagnosis of these fevers is always a difficult matter, especially so during their early stages. Among other possibilities that of typhoid, of undulant (Mediterranean) fever, of malaria, of kala-azar, of dengue, of influenza, and of other infections has to be considered. The persistent absence from the blood of the malaria parasite and of pigmented leucocytes —if vouched for by an experienced observer—and the negative results attending administration of quinine, together with the absence of definite periodicity in the symptoms, of pronounced anæmia and of marked

enlargement of the spleen, should be decisive against malaria. But in the present state of our knowledge it is very hard indeed until the case is well advanced to exclude typhoid, paratyphoid, and undulant fever. It may be that further experience of the blood-serum tests will establish their title to be regarded as absolutely pathognomonic signs. In this event the practitioner will have in his possession an invaluable aid in the diagnosis of tropical fevers. As things are at present, in cases in which there is the slightest doubt it is an excellent rule to regard all doubtful fevers as being possibly typhoid.

Treatment.—It is well at the commencement of doubtful tropical fevers to be as guarded in treatment as in diagnosis, and to eschew active purgatives, to enjoin rest in bed, to place the patient on a bland, unstimulating fluid diet, and to confine medication to some innocent fever mixture. There is no specific treatment for any of these imperfectly differentiated fevers. Each case has to be dealt with on its own merits and on general principles. Headache may be relieved by cold applications to the forehead, by an ice cap, or, especially if temperature rises high, by sponging and, if not otherwise contra-indicated, by occasional doses of phenacetin or some similar drug. If quinine, on the supposition that the case is malarial, has been freely tried, and without benefit, it must not be persisted with. As already hinted, "low fever" should be treated by change of air, and more especially, where feasible, by a sea trip.

CHAPTER XXIII

PELLAGRA

Synonyms. — Pellarella, Alpine scurvy, Asturian leprosy, Asturian rose, disease of the Landes, dermotagra.

Definition.—An endemic disease of slow evolution, characterized by a complexity of nervous, gastric, and cutaneous symptoms, which make their first appearance during the spring months, and recur year after year at the same season, remitting more or less during the winter months. It is for the most part confined to field labourers. The more distinctive features are—(*a*) a remitting erythema of the exposed parts of the body; (*b*) marked emaciation; (*c*) profound melancholia alternating with mania.

Geographical distribution. — *Europe:* Pellagra has a wide distribution in Southern Europe. It is found in Northern Portugal, in Spain, in Italy, in the south-west of France, in the Austrian Tyrol, in Hungary, Croatia, Dalmatia, Bosnia, Servia, Bulgaria, Turkey, Greece, Corfu, Roumania, Bessarabia, Kherson, and Poland. Cases have been discovered recently in England and Scotland. *Africa:* Algeria, Tunis, Egypt, the Red Sea coast, Rhodesia, Nyasaland, and among the Kaffirs and Zulus. Sandwith found it in 1900 among the coloured lunatics on Robben Island. *Asia:* Information is scanty, but it has been reported from Asia Minor and North Behar in India (Ray, 1902), Singapore, Philippine Islands. *America:* The United States, Mexico, Central America, Brazil, the Argentine, Barbados, and probably in other West Indian islands. *Australasia:* Neirte has reported it in New Caledonia.

History.—The history of pellagra is comparatively recent. The disease was recognized and described almost simultaneously in Italy and Spain. In Spain it was first described by Casal in 1762 under the name of *mal de la rosa*, but he stated

that the disease had been endemic in Oviedo since 1735, although unknown in other parts of the Asturias. Subsequently it became widely diffused throughout the Iberian peninsula. In Italy the disease, under the name of Alpine scurvy, was described by Odoardi in 1776, but it had been recognized previously by Pujati in 1740. Ramazzini, in 1700, writes of a disease under the name of *mal del padrone*, which appears to have been pellagra. Frapolli, who described the disease in 1771, under the name of pellagra, says that probably it is the same as pellarella, a disorder mentioned as early as 1578 in the rules of admission to the Ospedale Maggiore in Milan. Pellagra appeared first in the provinces of Lombardy and Venice. By the end of the eighteenth century it had spread over the greater part of northern and middle Italy. Quite recently it has appeared in the southern provinces, in Sardinia and Sicily, regions previously immune.

The earliest mention of pellagra in France dates from 1829, when Hameau published an account of cases observed since 1818 around Teste-de-Buche and in the plain of Arcachon. He describes its subsequent spread in the coast region of the Gironde.

In Roumania the first appearance of the disease is assigned to the year 1833; in Corfu, to 1839.

We know nothing of the history of pellagra in Egypt prior to the publication of Pruner's "Topographie Médicale du Caire," in 1847. Pruner's statements were discredited by Hirsch and others, but recently Sandwith has shown that the disease is very prevalent in Lower Egypt, and also, though to a less extent, in Upper Egypt. In the United States of America, although there is evidence of its sporadic occurrence there for a considerable time—at least fifty years—before its nature was recognized, pellagra was first diagnosed as such in 1907. It is prevalent especially in the south-eastern States, and is rapidly increasing. Lavinder states that there are now 15,370 cases in eight southern States. It has been estimated that there are upwards of 30,000 cases in the United States.

Etiology. *Sex.*—Both sexes are liable; as a rule the disease is more prevalent in men. The degree of prevalence amongst women varies greatly in different places, apparently according to the share they take in field work.

Age.—Pellagra is chiefly a disease of middle age, the majority of cases occurring between 20 and 50. Infants are sometimes, though very rarely, attacked. Sambon saw an infant of 3 months with characteristic symptoms.

Occupation.—The disease is most prevalent among field-labourers. The inhabitants of towns, even of

those in the very heart of intensely pellagrous districts, enjoy an immunity similar to that of town-inhabitants as regards malaria. Felix points out that pellagra is quite exceptional among the Jews, who, as a race, rarely engage in agriculture. Bouchard says that herdsmen in pellagra regions are exempt. Although pellagra occurs most frequently in field-labourers living from hand to mouth, it does attack people in good circumstances. This has long been recognized in Italy, and the figures given by Gruner for the southern States of the United States—258 cases had lived in poverty, 59 in comfort, 6 in affluence—show that the same remark applies to America.

Season.—In the northern hemisphere the disease first shows itself in the spring months (February, March, April), and its relapses take place year after year at the same season. Occasionally relapses occur in autumn.

Topographical distribution.—This has been carefully studied by Sambon in Italy and, in conjunction with Chalmers, in Roumania. As regards Italy, Sambon finds that the disease is strictly confined to —or, rather, can be acquired only in—certain well-defined and limited areas situated along the banks of streams (usually fast-running), the haunts of a special insect—simulium. He maintains, apparently on adequate evidence, that if the disease is encountered elsewhere the patient must at one time have resided in one of the endemic localities.

Epidemiology.—Pellagra is regarded as being strictly endemic, but everywhere it has shown a marked tendency to slow extension. Thus, still very common in the north of Italy, where it first appeared, pellagra in recent years has become increasingly prevalent in Umbria and in the Marche, and has extended to the provinces of Siena and Grosseto in Tuscany, those of Campobasso, Teramo, and Aquila in the Abruzzi and Molise, the province of Rome, the Campagna, the Puglie, Sicily, and Sardinia. When once established in a district it remains there, but the degree of prevalence varies considerably from

year to year, and not always in direct ratio to the amount of rainfall or the hygrometric state of the atmosphere, as has been asserted. In proportion as the area of pellagra has extended, the number of cases in the original seats of the disease has usually increased. Thus, the number of pellagra patients in Lombardy in 1839 was 20,282; in 1856 it had risen to 38,777; in 1879 to 40,838; in 1881 to 56,000; in 1889 to 72,603. According to official figures it had fallen to 33,869 in 1910, the decrease being attributed to the enforcement of sanitary laws directed against the disease.

The virus.—Pellagra has been ascribed to the most varied causes, such as insolation, poverty, insanitary dwellings, syphilis, irritant oils, bad water, alcohol, garlic, onions, maize. Some have regarded it as a modified or degenerate form of leprosy, others as "sunstroke of the skin," and D'Oleggio, in 1784, proposed that it should be called "vernal insolation." "Sun disease" was an old popular name, and certainly the skin manifestations of pellagra are influenced by the action of the direct rays of the sun. This was proved experimentally, first by Gherardini, who varied the limits of the eruption by systematically displacing parts of the clothing; and later by Hameau, who obtained differently shaped patches of erythema by means of gloves fenestrated in different ways. In smallpox and also in other exanthemata we notice a decided influence of light, more particularly of the actinic rays, on the production of their skin eruptions. Although light may influence the eruption in pellagra, this is no adequate reason for concluding that insolation is the cause of the disease, any more than that it is the cause of smallpox. In support of the sunlight hypothesis, certain experiments on the effect of sunlight on animals fed on a too restricted (unphysiological) diet have been advanced recently; but it is evident from what we now know of the seasonal, epidemiological, and topographical habits of pellagra that such an hypothesis is untenable.

It would be idle to discuss the arguments brought

forward to show that pellagra is caused by bad water, insanitary dwellings, poverty, syphilis, leprosy, alcohol, oil, onions, or garlic. The maize theory, on the other hand, demands, because of its popularity, a searching scrutiny.

The general opinion is that pellagra appeared soon after the introduction of maize into Europe, and that it advanced *pari passu* with the extension of maize cultivation, and with the more general adoption of the new cereal as an article of food. For these and other reasons maize is held to be the causative agent of pellagra, as a condition of rye is known to be the cause of ergotism; and, just as in the latter case, various theories have been advanced to explain the operation of the assumed cause.

The morbific action of maize has been variously attributed to—

(*a*) Deficiency in its nutritive principles.

(*b*) Specific toxic substance contained normally in the grain.

(*c*) Poisons elaborated after it has been ingested.

(*d*) Toxic substances elaborated during decomposition of the grain.

(*e*) Fungi or bacteria found on maize.

(*a*) *Deficiency in nutritive principles.*—Maize stands high as regards alimentary value. Insufficient nourishment may bring about inanition and marasmus, but never causes specific lesions like those of pellagra. Entire populations who live solely on rice or potatoes remain quite free from this disease, although these foods are far inferior to maize in nutritive value.

(*b*) *Specific toxic substances normal to maize.*—Those who advanced this theory were obliged to stipulate for a special personal susceptibility, otherwise the immunity of the millions who live on Indian corn could not be accounted for.

(*c*) *Poisons elaborated from maize within the alimentary canal*—Neusser regards pellagra as a peculiar form of auto-intoxication. A similar theory was propounded by De Giaxa in 1903. The latter ascribes the disease to a poison resulting from the action of *Bacillus coli* on sound maize after ingestion. He claims to have produced the anatomical lesions of pellagra in dogs by feeding them on porridge made with sound maize, and also to have obtained the same symptoms and lesions in animals inoculated with a toxin produced *in vitro* by the cultivation of *Bacillus coli* in maize media. These theories are disposed of by the harmlessness of maize in non-pellagrous districts.

(*d*) *Toxic substances elaborated in decomposing maize.*—Lombroso, in 1871, claimed that pellagra is due to the ingestion of certain toxic substances elaborated by saprophytes acting on the grain. In conjunction with others, he obtained from fermenting maize a watery extract containing a narcotic principle resembling conin, and also an alcoholic extract and a red oil, both containing an alkaloid resembling strychnine, "pellagrozein." These two toxins combined, he holds, give rise to pellagra in the same way as sphacelinic acid and cornutin are believed to give rise to ergotism. In fowls inoculated with the toxins, Lombroso observed diarrhœa, loss of feathers, and death; in rats, wasting, choreiform movements, muscular spasm, and death; in men, vomiting, diarrhœa, desquamation of the epidermis, giddiness, dilatation of the pupil, and malnutrition.

These acute symptoms are in no way comparable to pellagra; identical results follow the administration or inoculation of analogous substances prepared by similar methods from wheat and other harmless foods.

Different investigators have extracted from damaged maize very different substances. Hausemann found a narcotic tetanic poison which he called "maizina." Selmi demonstrated the presence of ammoniacal acrolein. Pellogio extracted a bitter substance which produced paralytic symptoms. In 1881, Monselice analysed various specimens of damaged maize collected in pellagra districts, but was unable to find any alkaloid; he pertinently remarks that artificially fermented maize and the ordinary damaged maize are two very different things. In 1894, Pelizzi and Tirelli made experiments on dogs and rabbits, administering per os, or injecting subcutaneously or endovenously, the toxic substances obtained from cultures of the bacteria of maize. They observed spastic paresis of the posterior limbs and other symptoms which they considered characteristic of pellagra. Gosio, having observed that the commonest saprophyte of maize is *Penicillium glaucum*, prepared pure cultures of this fungus and extracted a substance belonging to the aromatic series. Ferrati made some experiments with a tincture of penicillium-damaged maize, and found that it is exceedingly toxic to rats, the animals dying in a few hours. Di Pietro noticed that only a certain variety of *Penicillium glaucum* has toxic properties. The poisonous substance is not present in cultures before the third day; it is a glucoside, and is found in the spores only. Experiments on guineapigs, dogs, cats, and rabbits produced symptoms very different from those obtained by Lombroso and others, but Di Pietro considered them characteristic of pellagra. Di Pietro also tested the toxic properties of *Penicillium glaucum* on himself, and suffered from pyrosis, vomiting, giddiness, weakness in the legs, slight tremor of the arms, frequent micturition. Lastly, in 1904, Fossati declared that he induced pellagra by feeding or inoculating guineapigs with maize damaged either by *Aspergillus fumigatus* or *Penicillium glaucum*. These results are mutually contradictory.

(*e*) *Micro-organisms found on maize.*—Ballardini, in 1845, was the first to attribute pellagra to a living organism, a mould (*Sporisorium maydis*), which he found in the greenish stain (verderame) frequently seen in the germ-groove of maize grains. Experiments gave rise to gastritis and diarrhœa in man, loss of feathers and general wasting in fowls. Lombroso pointed out that *Sporisorium maydis*, on account of its rarity, could not be the cause of pellagra, and that Ballardini had probably confounded the *Sporisorium* with *Penicillium glaucum*. A special commission reported against Ballardini's discovery, on the ground that the verderame was common in many non-pellagrous districts of Italy. However, notwithstanding this, Ballardini's theory was accepted by many in Italy, and by Roussell and Costallat in France.

In 1860, Pari incriminated the maize smut (*Ustilago maydis*), pointing out that the spores of this fungus are invariably present in the dust of the hovels of the peasants, who store their maize in the rooms in which they sleep. Generali fed two horses on fodder mixed with the maize smut, and claimed that after seven months one of the animals presented a skin eruption on the parts most exposed to the sun. But Prof. Imhof, who made some experiments on himself, proved that the maize smut is harmless to man.

In 1881, Majocchi found in both normal and diseased maize a very motile micro-organism which he named *Bacterium maydis*. He claimed to have found this organism in the blood, brain, liver, heart, kidneys, lungs, intestinal mucosa, and erythematous skin of pellagra patients, and on these grounds brought it forward as the causative agent of the disease. Cuboni found a similar bacillus in damaged maize, and in the stools of pellagra patients. Paltauf, who investigated pellagra in 1889 on behalf of the Austrian Government, examined fifteen patients, but found Cuboni's bacterium in the stools of one only. However, he found it to be a very common saprophyte of damaged maize, and, together with Heider, proved that the maize toxins were partly due to the metabolic action of this organism. At the same time he showed that *Bacterium maydis* is no other than the well-known potato bacillus (*Bacillus solanacearum*) and that its toxic effects do not resemble pellagra.

In 1896, Carrarioli also claimed to have found a bacillus in the blood, saliva, and stools of pellagra patients. He stated that he had inoculated the toxic products of this organism subcutaneously into various animals, and that he also had invariably obtained symptoms similar to those of pellagra. He went so far as to name the organism *Bacillus pellagræ*.

In 1902, Ceni stated pellagra to be a true mycosis due to two different species of *Aspergillus*, *A. fumigatus* and *A. flavescens*. He declared that the season in which pellagra symptoms appear in man corresponds to "the cycle of annual biological evolution" of these hyphomycetes. Moreover, he stated that he had been able to isolate almost constantly, and usually in pure

culture, the two Aspergilli from the lungs, pleura, pericardium, and meninges of pellagra cadavers, and, further, that the spores of the fungi pass through the intestinal wall and thus reach the other organs.

In a later work Ceni, together with Besta, ascribes pellagra not to the organisms themselves, but to elaborated toxins. More recently Ceni and Besta describe two special varieties of *Penicillium glaucum* as the true cause. According to these authors the toxic properties of one variety are excitative and therefore cause the acute forms of the disease; those of the other, being narcotic, give rise to a more chronic type. Tiraboschi, who has made (1905) a very careful study of the hyphomycetes found on maize grains in pellagra districts, states that he never found *A. flavescens*, and believes that Ceni and Besta must have confounded it with *Aspergillus varians*, which is very common. He also states that *A. fumigatus* is rare, while Ceni and Besta stated that both *A. flavescens* and *A. fumigatus* are very common, and in some seasons even more common than *Penicillium glaucum*.

The fungus incriminated by the majority of authors as the causative agent of pellagra is, strange to say, the common blue mould, *Penicillium crustaceum* (*P. glaucum*), which is found everywhere and on the most heterogeneous media.

In contemplating the fungus theory of pellagra it is interesting to note that of all the diseases known to be caused by fungi, such as thrush, ringworm, pinta, tinea imbricata, mycetoma, actinomycosis, pneumonicosis, not one in any way resembles pellagra.

In examining the numerous observations that have been made, there is one fact which stands out very prominently, and that is that each investigator claims to have reproduced true pellagra either in animals or man, sometimes in himself, by inoculating beneath the skin, injecting into the veins, or administering per os the special organism or toxic product which he happens to have isolated. But the peculiar symptoms and anatomical lesions of pellagra, together with its epidemiology, seasonal habit, and geographical distribution, show very clearly that the disease must have one specific cause and cannot be brought about by each, or all, or any of the numerous aforementioned fungi, bacteria, and chemical products. It would be unwise, therefore, to place much reliance on these experiments. The interpretation of experiments is often as fallacious as the interpretation of ordinary natural facts. The history of the investigation of almost every disease furnishes examples in plenty.

The maize theory of pellagra is based chiefly on the belief that the disease appeared soon after the introduction of maize into Europe, and that it everywhere followed the extension of maize cultivation, and increased with the more general adoption of the new cereal as an article of food. This opinion has been repeated by almost every writer on pellagra. Neither the statement nor the argument is indisputable. In the first place, we know nothing positive about the introduction of maize into Europe. The general belief is that it was brought over by the Spaniards from South America; on the other hand, there is historical evidence that maize was cultivated in the Old World hundreds of years before the discovery of America. Although we have no positive information as to the date of its introduction into Italy, it is certain that maize was used there as an article of food about the middle of the sixteenth century, that is to say, about 200 years before the date assigned to the appearance of pellagra. We are thus confronted by a very serious dilemma, for if we allow that pellagra existed and was known, it may be under other names, previous to its recognition by Frapolli in 1771, then we can no longer assign a date for its introduction into Italy, and thus the most powerful argument in favour of its association with maize is lost. If, on the other hand, we maintain that pellagra did not exist in Italy prior to that date, then it is difficult to explain why it did not show itself soon after the introduction of the incriminated cereal.

It has been pointed out again and again by numerous observers that the areas of pellagra endemicity and those of maize culture do not correspond; indeed, there are vast regions in which maize is extensively cultivated and much eaten, but in which pellagra until comparatively recently was absolutely unknown. A leading example is that of the United States of America. On the other hand, pellagra has been observed very frequently in places in France, Spain, and Italy, not to mention Great Britain, in which maize is not cultivated and in

people who have never used it as an article of food. To overcome these embarrassing facts, so telling against the maize theory, the comfortable term "pseudopellagra" was invented. The disease is pellagra when it fits in with the orthodox theory and when it can be connected in any way with maize; but when this is not possible, the disease becomes a "pseudopellagra"!

A comparative study of the distribution and prevalence of pellagra at different periods is decidedly unfavourable to the maize theory. In the days of Casal the province of Oviedo in Spain was one of its chief centres. In 1900 this was the province which suffered least, the highest incidence of the disease being in the province of Madrid. Now, no change whatsoever has taken place in the maize cultivation of the province of Oviedo; the people eat maize there to-day just as freely as they did in Casal's time, and there has been no improvement in the storage or preparation of the grain. On the other hand, maize is hardly ever used as an article of food in the province of Madrid.

After pointing out (*Brit. Med. Journ.*, 1905) how unsatisfactory are the prevailing theories as to the causation of pellagra, Sambon suggests that it probably belongs to the protozoal group of diseases. The skin lesions, the chronic course, the implication of the nervous system, the beneficial effect of arsenical treatment, he claims, support the protozoal hypothesis. The mononuclear increase in the blood of pellagra patients is an additional argument in favour of the suggestion.

Sambon goes farther than this. He has advanced the hypothesis that the hitherto unrecognized protozoal cause of pellagra is insect-borne, and probably by a species of simulium (*S. reptans*). In favour of this hypothesis he adduces not only the analogy of malaria and trypanosomiasis, but the facts that pellagra is a rural and not an urban disease—that is, it does not occur where simulium is absent; that it affects principally field-labourers—that is, those mos exposed to the attacks of simulidæ; that it occurs

only where these insects abound—that is, in the neighbourhood of streams. In his reports he describes many circumstances observed in Italy and elsewhere in support of his views; perhaps the most telling is that which refers to the islet of Burano, in the vicinity of Venice. Pellagra is common in Burano and on the neighbouring mainland. But whereas on the mainland the principal sufferers are women, in Burano the disease is confined to men. There are no streams in Burano, and consequently no simulidæ. How account, then, for the local pellagra? And how account for the disease being confined to men? According to Sambon, the explanation lies in the circumstance that the men, in their vocation as fishermen, often have occasion to visit the mainland and to pass the night there, and are consequently exposed to the bites of simulidæ; whereas the women, having no occasion to leave the island, escape infection.

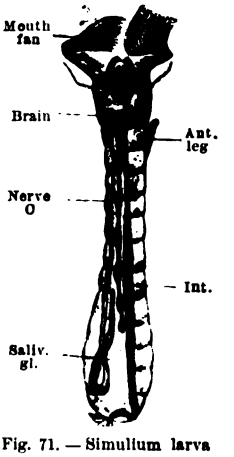


Fig. 71. — Simulium larva (*Drawn by W. McDonald.*)

Before Sambon's theory can be accepted, many facts, apparently incompatible, have to be explained, as, for instance, the absence of simulidæ in Egypt, Barbados, etc., where pellagra is so rife.

Simulidæ are minute (1–4½ mm.), thick-set, dark-coloured flies, provided with moderately long legs—often banded with white, and large, broad, transparent wings. They are known in America as "buffalo gnats." They have a peculiar dancing flight, and the females are vicious biters (the males are inoffensive). The eggs are laid in patches on stones or water-weeds, to which they become attached. The larvæ are unmistakable; they have an elongated, club-shaped body, of a greenish-brown colour, supplied with a large terminal sucker at the larger posterior extremity, by means of which they attach themselves to pebbles, water-weeds, and drift-wood. The larva spins a silken thread which offers a further means

of attachment and serves to weave the characteristic pocket or slipper-like cocoon at the time of pupation. The cocoon is open at the larger anterior end, from which protrudes the anterior portion of the pupa with two lateral tufts of long feathery filaments. (Figs. 71, 72, 73.)

Symptoms.—Pellagra usually begins with feelings of weakness and a consequent disinclination to work. The patient is pale, has a peculiar staring

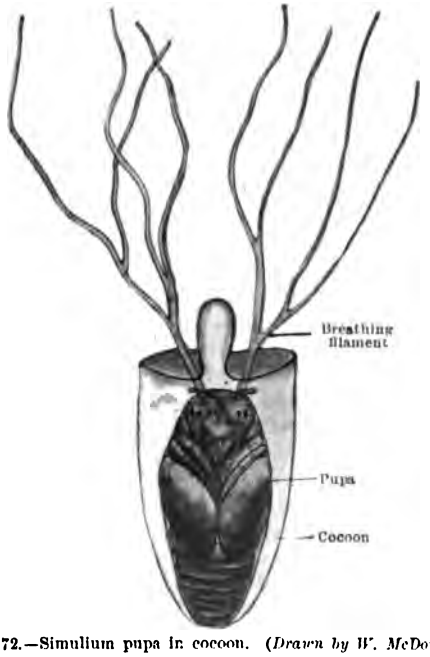


Fig. 72.—Simulium pupa in cocoon. (*Drawn by W. McDonald.*)

look, and complains of headache, giddiness, and vague but often severe pains in the back and joints. His character changes; he becomes irritable, and at the same time stupid and morose.

At first the tongue is coated; later it loses its epithelium, the denudation extending not infrequently to the palate and gullet, and giving rise to a sore condition, often accompanied by a saltish taste and

copious salivation. The gums may be swollen and bleed easily, a condition which gave rise to the name "Alpine scurvy." There may be eructations of gas, nausea, and vomiting. The appetite is variable. The epigastric region, and sometimes the lower part of the abdomen, are tense and painful. Constipation may be present, but in many instances there is diarrhœa of pale fermenting stools resembling those of sprue,* and the stools may contain blood.

From the commencement an erythema, not unlike a severe sunburn, is observable on those parts of the body which are, as a rule, unclothed and exposed to the sun. The eruption is symmetrical and characteristic. (*See* Frontispiece.) It appears suddenly, first on the back of the hands and feet, then on the forearms, legs, chest, neck, face, and, it may be, on the perineum, or on the female genitalia. The patches of erythema are irregular in outline and intensity. The affected area is swollen and tense, and the seat of burning or itching sensations which become particularly acute on exposure to the sun. The congestion disappears completely, but temporarily, on pressure. Petechiæ are common on the affected parts, and blebs may form with clear, opaque or blood-stained contents of feebly alkaline reaction. The eruption usually lasts about a fortnight, and is followed by desquamation, which leaves the skin rough, thickened, and permanently stained of a light sepia

Fig. 73.—Simulium nigrogilvum, imago. (*Drawn by W. McDonald.*)

* The Barbados form of pellagra, if it be pellagra, has been called "psilosis pigmentosa," the cutaneous and nervous affections being those of genuine pellagra, the gastro-intestinal symptoms being those of sprue (psilosis).

colour. It is on account of this roughness of the affected skin that the disease is called "pellagra," an Italian word meaning rough skin.

Implication of the nervous system is indicated by tremor of the tongue, exaggerated deep reflexes, and mid-dorsal spinal tenderness. The patient suffers from obstinate sleeplessness, occasionally from uncontrollable sleepiness. He experiences great weakness, especially in the lower extremities, and is subject to peculiar attacks of giddiness, with a tendency to fall forwards or backwards. Another characteristic symptom is a feeling of burning in the palms of the hands and the soles of the feet. "Chvostek's sign," mechanical irritability of the facial nerve, is said to be present in the majority of cases.

As a rule there is no marked permanent elevation of temperature, but periods of slight fever occur irregularly.

Two or three months after onset the symptoms abate and, although the affected skin areas remain dark-coloured and rough, the disease appears to be arrested. Next spring, however, the whole series of phenomena recurs in a more severe form. The eruption assumes a darker colour. The depression of spirits deepens into melancholia, which may have maniacal interludes, with a peculiar tendency to suicide, especially by drowning. The general feeling of weakness increases, the patient loses weight and is unable to work; his gait becomes uncertain and somewhat of the spastic paraplegic type. The pains in the head and back become very acute, and there may be lightning pains, cramps, twitchings, tremors, and even epileptiform seizures of the cortical variety. Diarrhœa may now be troublesome.

For several years the disease may thus recur in the spring with increasing severity. The patient becomes greatly emaciated, paralytic, and completely demented. Helpless, bedridden, suffering from incontinence of urine and uncontrollable diarrhœa, covered with bedsores, and neglected, he dies from exhaustion or from some intercurrent disease.

The duration of pellagra is exceedingly variable.

It may last only two or three years; it usually extends to ten, fifteen, or more.

In a proportion of cases, more especially if the patient leaves the endemic area and comes under favourable hygienic influences early in the disease, recovery may take place.

Cases differ considerably. In some the nervous symptoms predominate, in others the gastro-intestinal, in others again the cutaneous. Forms of hyperæsthesia may occur in different regions of the body. Ocular symptoms, such as ptosis, hemeralopia, diplopia, amblyopia, mydriasis, are not uncommon. The urine is generally alkaline, and may rapidly become ammoniacal. It may contain tube casts and traces of albumin. The erythrocytes and hæmoglobin are diminished. Sambon and Terni in Italy, Grigorescu and Galasescu in Roumania, have noticed a relative increase of the mononuclear leucocytes, a point differentiating the eruption of pellagra from ordinary erythemas; but it cannot be said that although usually disturbed the differential leucocyte count is constant or characteristic.

A very acute form has been described under the name of "pellagra typhus." In this there are intense prostration, high temperature, delirium, trismus, stiffness of the neck, and sometimes opisthotonos. This pellagra typhus may be ordinary pellagra complicated with other diseases, such as enteric, cerebrospinal or malarial fever. It has been remarked that in countries in which pellagra has been recently introduced the type of disease is usually of a very virulent nature.

It has been estimated that in Italy from 4 to 10 per cent. of the pellagrins become permanently insane. Similarly, in the United States of America the pellagrins are becoming a notable feature in the lunatic asylums.

Morbid anatomy.—The pathological characteristics essential to pellagra are usually obscured by complicating diseases.

A constant and striking feature is the great emaciation. The viscera show chronic degenerative

changes, particularly fatty degeneration and a characteristic deep pigmentation. The intestinal walls are greatly attenuated through wasting of their muscular coat, while at the same time the mucous lining is hyperæmic and, not infrequently, ulcerated. The liver and spleen are usually atrophied.

There may be actual wasting of the brain, and the ventricles may be distended by an excess of fluid. In the cord the lateral columns and the crossed pyramidal tract are especially implicated, but the direct cerebellar tracts usually escape. The anterior cornual cells are frequently atrophied and deeply pigmented. The posterior columns do not escape, the median portion being often degenerated. The degenerative changes in the lateral columns are chiefly in the middle and lower third of the dorsal region, those of the posterior columns principally in the cervical and upper dorsal region.

Mott (*Brit. Med. Journ.*, July 3rd, 1913) has given a detailed account of the histological changes in the nervous systems of two cases of pellagra—one of English, the other of Egyptian origin. He remarks as to the changes in the cerebrum, cerebellum, pons, medulla, and spinal cord, that in none of the sections was there any evidence of meningeal or perivascular infiltration with lymphocytes, plasma cells or polymorphonuclear leucocytes. This absence of chronic meningo-encephalitis, a chronic inflammatory condition so characteristic of certain protozoal diseases, contra-indicates the protozoal theory of pellagra, although it cannot be said to disprove it, for in malaria the vessels may be crowded with parasites and yet no perivascular or meningeal reaction be detectable. Moreover, although all the changes were like those produced by a chronic toxæmia, the cause of that toxæmia has not been demonstrated. All the posterior spinal ganglia cells showed, in varying degree, a marked chromatolysis, swelling of cells and disappearance of Nissl's granules, and all the anterior horn cells and their homologues in the medulla and pons a varying degree of perinuclear chromatolysis. There was marked chromato-

lysis of the cells of Clarke's columns. The Betz cells of the cortex and the cells of Purkinje showed similar changes, but in a less degree.

Diagnosis.—Of course, doubtful cases are occasionally encountered, but a localized erythema associated with nervous symptoms, particularly mental symptoms, great debility and seasonal recurrence, in a person in or coming from a pellagrous district, can hardly be confounded with any other disease. Once seen, pellagra is easily recognized again.

Treatment.—Arsenic in large doses is now regarded as a drug of value in the treatment of pellagra. Fowler's solution by mouth—5 drops two or three times daily, increased by 1 drop daily until evidences of a toxic nature are induced—or hypodermically in combination with carbonate of soda (3 to 5 gr.) two or three times a week, is said to be productive of good results if given early in the disease, and, of course, combined with good hygienic conditions and removal from the endemic area. Atoxyl, soamin, and salvarsan have also been commended. No case should be regarded as cured until the patient has been absolutely free from all symptoms for at least two years.

In its advanced stage the disease is practically incurable. In Italy the Government, basing its action on the maize theory of pellagra, has provided grain-drying appliances for bakeries, and other hygienic advantages, including better house accommodation, also special asylums (*pellagrosari*) for the treatment of the disease in its earlier stages. It is stated that a decrease of the malady has followed these measures. Notwithstanding, pellagra seems to have increased of late years, especially round Perugia and in other districts of northern Italy in which these measures have been most strictly carried out.

As there has been no instance of a nurse or attendant in any of the lunatic asylums of the United States acquiring the disease, it is evident that pellagra is not a directly communicable disease, and that therefore any apprehension on this account is unwarranted.

CHAPTER XXIV

HEAT-STROKE

THE term "heat-stroke" conveys the suggestion that heat is the leading etiological factor in the various morbid conditions which custom has grouped under this and similar names.

Until irrefutable evidence has clearly demonstrated the true cause of any given disease, it is a very grave error to base the name of such disease on some crude hypothetical etiological conception. Such a nomenclature is sure to lead to confusion, to mistakes in practice, and to retard progress. There is no better illustration of the truth of this remark than that supplied by the group of diseases under consideration.

The expression "heat-stroke" covers several distinct, one might say of two of them almost opposite, clinical conditions. One of these is *heat-exhaustion*, virtually a syncope, which may occur anywhere and in any climate, high atmospheric temperature, whether natural or artificial, being its essential etiological factor. The other, of which hyperpyrexia is the most striking clinical feature, is a well-defined and possibly specific fever, having a peculiar endemicity and assuming at times in the endemic area almost epidemic characters. Like yellow fever, dengue, tropical elephantiasis, and other tropical diseases, this second form of heat-stroke occurs only in conditions of high atmospheric temperature; but, as with these diseases, it by no means follows that, though occurring *in* high temperature, it is caused *by* high temperature. To obviate confusion, and following the example of Sambon, I shall describe this disease under its ancient name *siriasis*.

Besides these two well-defined morbid states associated with high atmospheric temperatures there is another but ill-defined group of heat-stroke cases

which, to all appearance, result exclusively from exposure to the direct rays of the sun. These cases might be classified under the term *sun-traumatism.*

Although not all of them are strictly classifiable as fevers, in deference to custom and for convenience I shall describe these three phases of so-called "heat-stroke" in this place and as a group.

HEAT-EXHAUSTION

Definition.—Sudden faintness, or fainting, brought about by exposure to high atmospheric temperature.

Etiology.—The healthy human body, when untrammelled by unsuitable clothing, when not exhausted by fatigue or excesses, when not clogged by surfeit of food, by alcoholic drinks or by drugs, can support with impunity very high atmospheric temperatures. In many parts of the world men live and work out of doors in temperatures of 100° or even of 120° F. Many industries are carried on at temperatures far above this; glass-blowing, sugar-boiling, for example. The stokers of steamers, especially in the tropics, discharge for hours their arduous duties in a temperature often over 150° F.

When, however, the physiological activities have become impaired by disease, especially by heart disease, kidney, liver, or brain disease, by malaria, by alcoholic or other excesses, by fatigue, by living in overcrowded rooms; or when the body is oppressed by unsuitable clothing; or in the presence of a combination of some of these, then high atmospheric temperatures are badly supported, the innervation of the heart may fail, and syncope may ensue. Chevers, than whom few have had better opportunities of forming a sound opinion, speaking of this subject, says: "Numerous as the constitutional causes of heat-strokes are, all Indian experience combines to show that drunkenness is the chief." The tropical practitioner will do well to bear this remark in mind; it applies not only to heat-exhaustion, but also to all forms of disease grouped under the term "heat-stroke."

Heat-exhaustion, then, is one form of what, when the subject of it happens at the time to be exposed to the sun, is called "sun-stroke," or when the patient happens to be at the time under cover, is called "heat-stroke." In nine cases out of ten this sun-stroke, or heat-stroke, simply means syncope; syncope caused by solar or atmospheric heat, or a combination of these, acting on a body whose resistance has been impaired by disease, or by trying, unphysiological conditions. This form of heat-stroke, consequently, has no special geographical distribution and no special morbid anatomy or pathology. For obvious reasons it is most apt to occur in warm weather, and in tropical climates; and on this account its recognition, prevention, and treatment have special claims on the student of tropical medicine.

Symptoms.—When attacked with heat-exhaustion the patient feels giddy, and perhaps staggers and falls. He is pale; his pulse is small, soft, and perhaps fluttering; his breathing is shallow, perhaps sighing, never stertorous; his pupils are dilated; his skin is cold; his temperature is subnormal; and he may be partially, more rarely wholly, unconscious. Usually after a short time he gradually recovers; very likely with a splitting headache and feelings of prostration. In a small proportion of cases the faint is not recovered from, and death ensues.

Treatment.—In syncopal heat-stroke the patient should be laid at once on his back in a cool, airy, and shaded place. His clothes should be loosened, a little water dashed on his face and chest, and ammonia held to his nostrils. If necessary, a stimulant may be given by the mouth, or injected into the rectum or hypodermically. It is a mistake to douche these cases too freely. The object is rather to stimulate than to depress.

SIRIASIS

Definition.—An acute disease developing in the presence of high atmospheric temperature, and characterized by sudden incidence of hyperpyrexia, coma, and extreme pulmonary congestion.

Nomenclature.—This is, perhaps, the most important of the several diseases covered by those loosely used terms—sun-stroke, heat-stroke, *coup de soleil*, insolation, heat-apoplexy, heat-asphyxia, thermic fever, and so forth. I adopt the name siriasis because, whilst distinctive, it embodies no etiological theory; it has the further merit of being the most ancient of the many names applied to the disease.

The **geographical distribution** of siriasis appears to be remarkably restricted. Although it is true that this type, or what passes for this type, of disease has been reported as occurring in many countries, on making careful examination it will be found that a large proportion of the reputed cases are really examples of other diseases, more especially of cerebro-spinal fever, apoplexy, tubercular meningitis, delirium tremens, pernicious malaria, or some other phase of acute disease, but not of true siriasis. According to Sambon, hyperpyrexial heat-stroke is rigidly confined to certain low-lying, sea-coast districts, and to the valleys of certain rivers. It is never found in high lands, nor above a relatively low altitude—600 feet.

It is unknown in Europe. The endemic areas are—in America, the east coast littoral of the United States, more especially in the great towns, the Mississippi valley, the coast of the Gulf of Mexico, the valleys of the Amazon and of the La Plata, and the South Atlantic coast; in Africa, the valley of the Nile, the coasts of the Red Sea, and a low-lying part of Algeria near Biskra; in Asia, Syria, the valleys of the Indus and Ganges, Lower Burma, Tonquin, and south-east China; in Australia, the Murray River district, the Queensland coast, and, possibly, the plains of Sydney. No doubt it occurs elsewhere in corresponding meteorological and telluric conditions; but many large areas in the tropical world, and especially so the interior of continents, are exempt from siriasis. It is not met with on the high seas, although it is well known on ships in the narrow, land-locked Red Sea and the Persian Gulf.

Etiology.—New-comers to the endemic areas and Europeans are more liable than natives or residents of long standing. Apparently, long residence confers a relative although not an absolute immunity.

All ages and both sexes are susceptible; but, in consequence of their habits and more frequent exposure to the predisposing and immediate causes, men are more subject to siriasis than are women.

Predisposing influences similar to those in heat-syncope and sun-traumatism powerfully influence the liability to siriasis. Amongst these are all physiological depressants; notably intemperance, fatigue, overcrowding, unsuitable clothing, malaria, acute disease, and, also, chronic organic diseases of the important viscera.

Siriasis has generally been attributed to a direct action of atmospheric or solar heat on the body. Many theories of the *modus operandi* of this assumed cause have been advanced. Among these may be mentioned superheating of the blood by the high temperature of the surrounding atmosphere; paralysis of the thermic centres causing (*a*) over-production of heat, or (*b*) retention of body-heat; pressure on the brain by expansion from heating of the cerebro-spinal fluid; vaso-motor paresis; paresis of the heart ganglia; excess of carbonic acid in the blood; coagulation of myosin; suppression of sweat; deficient serosity of the blood from excessive sweating, and so forth.

It is well known that neither high atmospheric temperature *per se*, nor high bodily temperature, unless the latter be associated with some special toxins, gives rise to symptoms at all like those of siriasis. Considering these two facts, and at the same time the peculiar and capricious distribution of the disease, the circumstances that its prevalence curve does not always correspond with the atmospheric temperature curve; that the degree of prevalence varies in the endemic area from year to year; that it is not most prevalent in the hottest years, seasons, or places; that it becomes epidemic at times; that it runs a definite course; that it may

relapse; that in many instances it has definite premonitory symptoms; that it has peculiar lesions; and that it tends to terminate by crisis; in other words, that it behaves like pneumonia or any other specific fever—Sambon has boldly asserted that siriasis is a germ disease, like yellow fever or dengue, and, like these, is caused by some organism which demands for its development a high atmospheric temperature and certain, as yet unknown, local conditions. Time will show how far this hypothesis is correct. In my opinion it has more in its favour than any of the many theories that have been based on a purely thermic etiology.

Symptoms.—Though sometimes coming on suddenly during exposure to the sun, siriasis is very often preceded by a distinct prodromal stage. It is very often developed independently of any direct exposure to the sun; not infrequently the attack comes on during the night.

Among prodromata which may show themselves with greater or less distinctness for an hour or two or even for a day or two before the full development of the attack, may be mentioned great disinclination for exertion, pains in the limbs, drowsiness, vertigo, headache, mental confusion, sighing, anorexia, thirst, intolerance of light—sometimes accompanied by chromatic aberrations of vision, suffused eyes, nausea and perhaps vomiting, præcordial anxiety, sometimes a sense of impending calamity, an hysterical tendency to weep, a very hot dry skin, and a quickened pulse. Longmore called attention to excessive irritability of the bladder as a common prodromal symptom. This is a valuable and easily recognized danger-signal when present, and one the significance of which has been confirmed and emphasized by subsequent writers; it is possible, however, that its frequency has been exaggerated.

Though generally present in greater or less degree, and for a longer or shorter time, in many instances these prodromal symptoms are not remarked, the first indication of anything wrong being perhaps a short stage of restlessness, or possibly of wild

delirium. This brief preliminary stage rapidly culminates in coma, complete unconsciousness, and high fever, quickly passing into hyperpyrexia.

Wood thus describes the symptoms of the developed attack: "Total insensibility was always present, with, in rare instances, delirium of the talkative form, and still more rarely the capability of being roused by shaking or shouting. The breathing was always affected, sometimes rapid, sometimes deep and laboured, often stertorous, and not rarely accompanied by the rattle of mucus in the trachea. The face was often deeply suffused, sometimes with the whole face deeply cyanosed. The conjunctiva was often injected, the pupils various—sometimes dilated, sometimes nearly normal, sometimes contracted. The skin was always intensely hot, and generally, but not always, dry; when not dry it was bathed in a profuse perspiration. The intense burning heat of the skin, both as felt by the hand and measured by the thermometer, was one of the most marked features of the cases. The degree of heat reached during life was, in my cases, mostly 108°–109° F. The pulse was always exceedingly rapid, and early in the disease often wanting in force and volume; later it became irregular, intermittent, and thready. The motor nervous system was profoundly affected. Subsultus tendinum was a very common symptom; great restlessness was also very often present, and sometimes partial spasms or even violent general convulsions. The latter were at times epileptiform, occurring spontaneously; or they were tetanoid, and excited by the slightest irritation. Sometimes the spinal cord appeared to be paralysed, the patient absolutely not moving."

The pupils, unless immediately before death, when along with the other sphincters they relax, are contracted. The reflexes are partially or wholly in abeyance. There may also be, especially in the graver cases, free watery purging, the dejecta, as well as the skin of the patient, emitting a peculiar and distinctive mousy odour. The scanty urine may contain blood corpuscles, albumin, and casts.

Different writers mention a number of what may be described as minor symptoms. They vary in different cases, and are by no means always present or characteristic. Whether these minor symptoms are present or not, in siriasis the essential symptoms—high fever and profound nervous disturbance, generally associated with insensibility—are invariably in evidence.

Unless active measures to lower temperature are taken early in the progress of the case, and unless these measures are vigorously carried out, in the great majority of instances death will occur within a few hours, or even minutes, of the onset of insensibility. The immediate cause of death is generally the failure of respiration. Rarely do cases linger for a day or two. Partial recovery is sometimes followed by relapse. In favourable cases the disease usually terminates by crisis. Convalescence is rapid.

Mortality.—As might be supposed, some types of heat-stroke are much more dangerous than others; siriasis infinitely more so than ordinary heat-exhaustion. Treatment, if early instituted and judiciously carried out, has undoubtedly a powerful influence in reducing mortality. Taking one type of heat-stroke with another, the case mortality among English troops in India is about one in four; in the year 1892, of 223 European soldiers admitted to hospital for heat-stroke, 61 died.

Morbid anatomy.—A notable feature in fatal siriasis is the early appearance of rigor mortis. The blood is remarkably fluid, or but feebly clotted. The venous system is loaded, dark fluid blood pouring from the phenomenally engorged lungs and other viscera on section. Both blood and muscles are said to yield an acid reaction more or less pronounced. It has been stated that the red blood-corpuscles are crenated, and do not form rouleaux. If the post-mortem examination is made shortly after death and before decomposition changes have set in, the heart in early rigor mortis, particularly the left ventricle, will be found to be remarkably rigid; this rigidity is sometimes described as being of woodeny hardness.

There may be some venous congestion of the meninges, but the brain itself shows no important vascular, or naked-eye, changes. The intestinal mucosa, as well as that of the stomach, is swollen and exhibits patches of congestion.

Pathology.—As may be gathered from the remarks on etiology, the pathology of siriasis, so far, is in a very unsettled state, and will continue to be so until the essential cause of the disease has been finally determined.

Diagnosis.—The presence of high fever is sufficient to differentiate siriasis from sudden insensibility caused by uræmia, by diabetic coma, by alcoholic and opium poisoning, and by all similar toxic conditions. Cerebral hæmorrhage, particularly pontine, may, after some hours, be followed by high temperature; but here the febrile condition follows the insensibility, whereas in heat-stroke the febrile condition precedes insensibility. The diagnosis from a cerebral malarial attack may be very difficult; chief reliance has to be placed on the history—if obtainable, on the condition of the spleen, and, especially, on the result of microscopical examination of the blood. Malarial fevers, and the early stages of the eruptive fevers in children, are very apt to be regarded as heat-stroke, particularly if there has been recent exposure to a hot sun. Cerebro-spinal fever, so often mistaken for siriasis, may be recognized by the occipital retraction, the irregular pupils, the frequent occurrence of strabismus, the comparatively low and fluctuating temperature, the associated herpes, the initial rigor, and its long duration.

Treatment.—In all fulminating fevers, including siriasis, occurring in warm climates, if malaria be suspected, particularly if the parasite be discovered in the blood, quinine should be injected hypodermically at once (7 to 10 grains of the bihydrochloride), or given by enema as directed under Malaria (p. 124); this dose should be repeated three or four times at intervals of four hours. In every case of siriasis, whether it has been deemed advisable to administer quinine or not, attention must at once be given to reduce

temperature by such rapidly acting measures as the cold bath, or ice applied in various ways to the head and body. Antipyretic drugs are of very little service, even if, in consequence of their depressing action on the heart, they be not actually dangerous: in all serious cases of siriasis such drugs must be carefully avoided. Chandler, speaking from an experience of 197 cases in which the mortality amounted only to 12, gives some excellent rules for the management of hyperpyrexial cases. He directs that the patient be placed undressed on a stretcher, the head end of which is raised slightly so as to facilitate the escape of involuntary evacuations and to provide for drainage. A thermometer is kept in the rectum. The body is covered with a sheet upon which are laid numerous small pieces of ice, larger pieces being closely packed about the head. Iced water is then allowed to drip for thirty or forty minutes on the patient from drippers hung at an elevation of from five to ten feet. A fine stream of iced water poured on the forehead from an elevation will act as a stimulant and rouser; this is a very powerful measure, and must not be kept up for longer than one or two minutes. A hypodermic injection of 40 minims of tincture of digitalis is given as soon as possible, its administration being preceded, in the case of plethoric patients showing much arterial tension (but not otherwise), by a small bleeding. The application of cold should be at once discontinued so soon as the thermometer in the rectum has sunk to 104°F, or, in cases of simple thermic fever in which the temperature has not exceeded 106°, when it has fallen to 102°. If these powerful antipyretic measures are carried beyond this point the fall of temperature may continue below the normal, even to as low as 91°, and dangerous collapse ensue.

On discontinuance of the iced sheet the patient should be wrapped in a blanket, and hot bottles applied to limbs and trunk. Very likely perspiration, a very favourable sign, will then set in. Stimulants may now be necessary. Strychnine, owing to the marked tendency to convulsions that is

present in heat-stroke, must on no account be used as a cardiac stimulant. Convulsions are best controlled by cautious chloroform inhalations. As death in heat-stroke generally results from failure of respiration, Chandler strongly recommends artificial respiration when the breathing threatens to become suspended ; he claims to have obtained some marvellous results from this expedient. It should be kept up for half an hour or longer.

During convalescence great care must be exercised to shield the patient from all influences calculated to provoke relapse.

SUN-TRAUMATISM

There is a large, ill-defined, and difficult-to-define class of heat-stroke cases which belong neither to the category of heat-exhaustion nor to the very definite and possibly specific disease just described. The morbid phenomena in this class of sun-induced disease are attributable, apparently, to a peculiar physical action of the direct rays of the sun on the tissues. To this category belong, it seems to me, those sudden deaths occurring without warning during, and manifestly in consequence of, exposure to the sun. Such may have been the sudden deaths described by Parkes, Maclean, Fayrer and others, in which soldiers in the excitement and stress of battle, while oppressed with thick clothing and heavy accoutrements and exposed to a blazing sun, suddenly fell forward on their faces and, after a few convulsive gasps, died. In these instantaneously fatal cases the paralysis of the heart or respiration seems to be of the nature of shock, as from a blow or other sudden and violent impression on the encephalon.

Doubtless, indeed it is a well-known fact, the strain undergone in these and similar circumstances may, in some instances, cause an apoplexy or rupture of some description in tissues prepared for such a cataclysm by morbid degenerations of long standing.

Besides the foregoing there is another type of case in which, after prolonged exposure to the sun, a febrile condition is established. This is sometimes of great

severity, being characterized by intense headache, a rapid full pulse, a pungent dry skin, intolerance of light, sound, and movement, and occasionally by vomiting or delirium. This condition suggests meningeal congestion, possibly inflammation. The acute phase may be quickly recovered from, or it may prove very persistent and last for days or weeks. It may leave no injurious effects; or it may be followed by a variety of transient or more permanent morbid nervous phenomena. Among the sequelæ authors have mentioned tremor, loss of memory, amaurosis, deafness, various paretic conditions, epilepsy, insanity, persistent headache, recurring headache, dyspeptic conditions. How far these sequelæ are entirely attributable to sun-exposure, or how far they depend on independent diseases, as syphilis for example, the local cerebral manifestations of which may have been provoked, though not actually caused, by the sun-traumatism, it is not always easy to say.

The **morbid anatomy**, as well as the clinical symptoms, indicates meningitis as a feature of these instances of reputed sun-traumatism. Authors refer to thickenings and opacities of the meninges, and even to thickening and roughening of the calvarium.

Many speculations have been advanced as to the **pathogenesis.** Manifestly it is not altogether, if at all, a question of caloric, for such effects do not result from exposure to the heat of a furnace, however intense. There appears to be some special element in the solar spectrum capable of injuriously affecting the tissues, particularly if they have not become gradually habituated to sun-exposure. That some such element does exist is proved by the phenomena of sun-erythema, of that form of skin pigmentation known as sun-burning, and, possibly, of leucodermia. The sensation of distress brought on by exposure to a hot sun, which is quite a different sensation from that produced by the heat of a fire, points in the same direction. In this connection we are forcibly reminded of the phenomena of the actinic rays of the solar spectrum, and of the remarkable tissue changes induced by the Röntgen rays.

Treatment.—Patients suffering from sun-traumatism must be kept as quiet as possible in a cool, airy, and darkened room. For a time the head should be kept shaved, and cold applied to the scalp. The bowels must be free; food should be light and unstimulating, and alcohol in every form strictly forbidden. Restlessness and insomnia are best treated by the bromides. For a considerable time the patient will be conscious of loss of memory, and feebleness of intellectual power and of the faculty of concentration. He may be irritable, liable to headache, and extremely sensitive to heat—more particularly the heat and glare of the sun. So soon as he is able to be moved he must be sent to a cold climate, and there remain until all trace of his illness has completely disappeared. Indeed, it is questionable if the subject of pronounced sun-trauma should ever again risk the dangers of a tropical climate; certain it is that he should not return to the tropics so long as the slightest evidence of cerebral trouble remains.

For persistent headache and other signs of chronic meningitis, courses of the iodides and bromides, repeated blistering of the neck and scalp, together with careful dieting and general hygiene, should be tried. In not a few instances, in spite of the most careful treatment, medicinal and climatic, serious permanent disease of the encephalon remains, giving rise to various and often incurable troubles, and, very commonly, to distressing intellectual enfeeblement.

Prevention of Heat-Stroke

In heat-stroke climates great attention should be paid to the general health; if this be not satisfactory, exposure to the sun and to high temperatures must, so far as possible, be avoided. Alcoholic drinks, gluttony, excess of animal food, too much tobacco-smoking—in fact, dissipation of all sorts—are especially to be deprecated. Individuals suffering from malarial or other fevers, or from chronic liver or kidney disease, run great risk if they are careless about exposing themselves to the sun. Violent

exercise, excessive fatigue, want of sleep, constipation, are also to be avoided.

Clothing ought to be light and loose fitting, the under-garment being of thin woollen material. In going out in the sun the head must be protected by a wide-brimmed, well-ventilated pith hat shielding the temples and neck as well as the top of the head. An actinic theory of sun-traumatism, advocated many years ago by Maude and Duncan, and more recently by Sambon (*Journ. of Trop. Med.*, Feb. 15, March 1, 1907), indicates the necessity for a radical change in the colour of the dress materials now in vogue among Europeans in the tropics. The natives of warm climates invariably have dark skins; a natural provision of protection against the actinic rays of the solar spectrum. Exposure to the sun tans the European; a natural protective reaction. Therefore the European in the tropics, conformably to this hint from Nature, should invariably wear non-actinic colours—a red or yellow shirt, or a fabric (solaro) into which these colours enter, and such as is now manufactured. The sun-hat should be similarly guarded. Experience has shown the comfort and value of such an arrangement. A pad of cotton sewn into the back of the coat in such a way as to protect the spine is a wise measure, and one adopted by experienced sportsmen in India. The phenomena connected with the Röntgen rays suggest the possibility that there may be solar rays other than the ordinary heat and actinic rays which, although they may be able to pass through organic materials, can nevertheless be arrested by metals. If this be true for the sun as well as for the Röntgen rays, a useful addition to the sun-hat would be a thin plate of some light metal placed between the layers of pith constituting the basis of the ordinary solar topee. A sheet of tinfoil or other light metal would not perceptibly add to the weight of the head-gear. Such sun-hats are, I believe, now manufactured. A white umbrella, lined with green or orange, ought never to be despised. Tinted (smoke colour) goggles are probably a protection, as they certainly are a great comfort in mitigating solar glare

Rooms should be kept dark during the day, and cooled by means of punkahs, thermantidotes, tatties, venetians, and other contrivances. In barracks and ships there must be no overcrowding. In very hot weather European soldiers should, if possible, sleep under punkahs. Military drills should be reduced to a minimum, and take place in the cool of the morning only, and after the soldier has had a cup of tea or coffee and some light food. Marches should be short, interrupted by frequent halts, and be got through if possible in the early morning. While marching the men ought to be in open order, relieved of all unnecessary weights, belts and clothing, and well supplied with water. Camps should be pitched in cool and airy spots and on turf and under large spreading trees free from undergrowth. Double canvas, one layer of which should be non-actinic, and grass or boughs laid on the wall of the tent, will do much to mitigate the temperature within.

Section II.—GENERAL DISEASES OF UNDETERMINED NATURE

CHAPTER XXV

BERIBERI (KAKKE, BARBIERS)

Definition.—Beriberi is a form of multiple peripheral neuritis occurring endemically, or as an epidemic, in most tropical and sub-tropical climates, and also, under certain conditions, in more temperate latitudes. The mortality is considerable, death usually depending on heart paresis.

Historical.—The special nature of beriberi was recognized by the Dutch in the early years of their intercourse with the East. Later, it was studied by British physicians in India, particularly by Malcomsen, Carter, Waring, and Morehead. It was not until a more recent epidemic in Brazil that beriberi began to receive attention from the present generation of medical men; and only when Anderson, Simmons, Scheube, and Baelz took up the subject in Japan was it studied by modern methods, accurately defined, and its true pathology apprehended. Scheube and Baelz were the first to show distinctly that beriberi is of the nature of a peripheral neuritis similar to that of diphtheria and alcohol—a view which was subsequently confirmed and adopted by Pekelharing and Winkler, and by most subsequent observers. More recently, and mainly owing to the investigations of Eijkman, Braddon, Fraser, and Stanton, its principal, if not its only, etiological factor has been shown to be a dietary of which the staple ingredient is over-milled rice.

Geographical distribution.—The area of the endemic distribution of beriberi is coextensive,

probably, with the tropical and sub-tropical belts; doubtless it exists in many places where its presence is not generally suspected. It is the scourge of many of the mines and plantations of the Malay and Eastern Archipelago. It is apt to break out among the coolie gangs engaged on extensive engineering works in the tropics, such as the Panama Canal or the Congo Railway. It haunts the Dutch army in Sumatra, and used to be common enough in the British armies in India. It is at home in many parts of Japan, particularly in her large, low-lying, damp, overcrowded cities. It occurs in China, the Philippines, the Eastern Peninsula, India, and Africa. It is prone to break out in gaols, in schools, in ships. Sometimes, as an epidemic wave, it passes over a tropical country, as was the case in the early 'sixties in Brazil, where it still lingers. Sometimes sporadic cases crop up here and there. Generally, when it appears in a community, it attacks large numbers, picking out particular houses and districts. Lately we had an account of a small epidemic among a group of Western Australian natives, and also among Chinese on the eastern seaboard of Australia, a continent where beriberi was formerly supposed not to exist. Similarly it appeared, apparently for the first time, in Japanese immigrants in Fiji. A little while ago I saw a case having the history and clinical features of beriberi from Lake Nyasa, another from the Upper Congo, another from Hayti. We hear of it also from Havana, from New Caledonia, from the Sandwich Islands, from Uganda—all of them places not before known to be liable to this disease—so that the area of distribution is an extensive one. Indeed, within the last few years it would seem that it includes the temperate as well as the tropical zones. Recently beriberi showed itself in a lunatic asylum in Ireland—Richmond Asylum, Dublin; and apparently the same disease has been seen lately in lunatic asylums in the United States and in France, and also among the fishermen on the North American coast.

Symptoms.—Medical visitors to the native hospitals in many parts of the tropical world are

likely to have their attention arrested by the large proportion of cases of partial paraplegia, of cases of œdema of the legs, and of cases of general dropsy. These, for the most part, are cases of beriberi.

Paraplegic cases.—On examining one of the paraplegic cases referred to (Fig. 74), it will be found that, besides paraplegia of greater or lesser degree, there is a certain amount of anæsthesia or of numbness of the skin; particularly of the skin over the front of the tibiæ, the dorsa of the feet, the sides of the thighs, perhaps also of the finger-tips, and of one or two areas on the arms and trunk. The visitor may be struck with the thinness of the patient's calves, the flabby state of the gastrocnemii; and by the fact that if, whilst making the examination, he should handle these and the neighbouring muscles somewhat roughly, particularly if he should squeeze them against the underlying bones, the patient will call out in pain and try to drag the limb away. The thigh muscles may be found to be similarly affected, and so may the thenar, the hypothenar, and the arm muscles; like the calf muscles, these too may be wasted and flabby. Very probably there is a loss of fat as well, the panniculus adiposus being every-

Fig. 74.—Paraplegic beriberi. (*Bentley.*)

where very meagre. If tested electrically, the muscles exhibit to perfection the reaction of degeneration. If the knee reflex be tested in the usual way, after the first week of the disease there will be no response whatever; nor can any clonus be elicited. As a rule, all the deep reflexes are lost; but the superficial reflexes, unless in extreme conditions of paresis and muscular atrophy, are usually present and more or less active. If, in severe cases, the patient is set to button his jacket or to pick up a pin, possibly he has a difficulty about it, or perhaps he cannot; he may bungle and fumble like an advanced ataxic.

There is more than ataxia, however; for the hand grasp is so enfeebled that the patient may have a difficulty in holding his rice bowl as well as in feeding himself. There is no tremor of the hands; and never or very rarely is there any paresis of the ocular muscles, or of the muscles of the face, of mastication, of the tongue, or of the pharynx. The sphincters and bladder operate satisfactorily, and the functions of the alimentary canal are carried on fairly well, although there is often some dyspeptic distension and oppression after food. On the patient being got out of bed and started to walk, if he is able to progress at all, his gait will be markedly ataxic; but he is not ataxic merely, for, just as with the hands, it will be seen that, in addition to want of co-ordinating power, there is great muscular weakness. If he is laid on the bed and asked to raise his legs, he is perhaps hardly able to get them off the mat, to cross them, or to place them one foot on top of the other. Very probably he is the subject of marked ankle-drop, so that he drags his toes when he attempts in walking to advance the foot; he has therefore to raise the foot very high, letting it fall on the ground with a flop when he brings it down again. His ataxia and his muscular weakness, as well as the partial anæsthesia from which he suffers, force him to adopt a variety of devices to assist him in progression (Fig. 75). Manifestly these patients are suffering from some form of peripheral neuritis.

The general health is good for the most part;

the tongue is clean, the bowels are fairly regular, there is no fever, and there is nothing amiss with the urine. Digestion, assimilation, and excretion go on satisfactorily.

Fig. 75.—Paraplegic beriberi. (*Bentley.*)

The heart and circulation. — When the heart is examined, if the case be at all recent or moderately severe, attention is at once arrested. On inspection it may be remarked that the impulse is diffuse, that there is epigastric pulsation; that the carotids throb too violently; that there is that peculiar wobbling

pulsating movement in the jugulars that denotes tricuspid insufficiency. On percussion the præcordial area is frequently found to be enlarged, perhaps very greatly enlarged, especially to the right; and on auscultation loud bruits, usually systolic in rhythm, may be heard. Marked reduplication of the sounds, particularly of the second sound, is to be noted. The auscultator may be struck, in a large proportion of cases, by the peculiar spacing of the intervals between the sounds. It may be hardly possible to tell by the ear alone which is the first pause and which is the second. They seem alike in point of duration; so that the sounds of the heart are, like the beats of a well-hung pendulum clock, evenly spaced, and not, as they are in health, separated by a long and a short interval like the beats of a badly hung clock. It will also be observed that the heart is very irritable, becoming easily quickened by exertion. It will be judged, therefore, that, in addition to peripheral neuritis, there is serious disease in the circulatory system, particularly in its innervation; that there is dilatation of the right side of the heart; and that there is a state of relaxed arterial tension.

All these signs and symptoms vary in degree from time to time in the same case, and differ in degree in different cases.

Dropsical cases.—In the next bed, perhaps, to the patient whose picture I have tried to draw may be seen another man suffering from apparently quite a different affection (Fig. 76). He is propped up in bed. Instead of being thin and wasted, as the last patient, his face is puffy and heavy; his lips possibly are slightly cyanosed; and his arms, hands, trunk, legs, and feet are distended with œdema. It may be thought from the œdema that it is a case of acute nephritis; but an examination of the scanty, dark-coloured urine shows that it is of high specific gravity, and contains no albumin, or only a mere trace; so that the case cannot be one of acute Bright's disease. Careful observation will discover that the œdema is somewhat firmer than that of nephritis, and, in not a few instances, that it does not involve the scrotum.

Occasionally cases are met with in which the œdema is peculiarly localized and fugitive. If attention is directed to the heart, a bruit and other evidences of dilatation of the organ and of arterial relaxation, just as in the first case, are discovered. If the lungs be examined, one may or may not discover signs of single or double hydrothorax, although, probably, not to a very great extent. The lungs themselves are healthy. On getting him out of bed it is found that the patient can hardly walk; partly from breathlessness, partly on account of mechanical interference by the dropsy with the movements of the legs, partly, perhaps, from some degree of paresis. He has ankle-drop possibly; and, if firm pressure be brought to bear on the calf muscles through the œdema, signs of hyperæsthesia of the muscles may or may not be elicited. Knee-jerk is probably absent, and there is numbness of the shins and finger-tips. The tongue is clean, the appetite fair, and there is no fever. But there may be complaint of præcordial distress and even pain, and, as this is aggravated by a full meal,

Fig. 76.—Dropsical beriberi. (*Bentley.*)

the patient eats sparingly. The amount of urine is generally very much reduced—to a few ounces even.

In this patient, therefore, there are the same signs of peripheral neuritis and of dilatation of the heart as in the other case. In addition, there is a somewhat firm œdema, which is not altogether cardiac, but, as its character and the circumstances in which it is found suggest, is probably connected partly with lesion of the nerves regulating urinary excretion, and partly with the play of transudation and absorption in the connective tissues.

Mixed paraplegic and dropsical cases. — In the next bed to this patient there lies, perhaps, another case which looks like a mixture of the two preceding. There is œdema—generally somewhat firm—particularly of the shins and feet, about the flanks, sacral region, and, very generally, over the sternum and root of the neck. There is numbness of the shins, there is some ataxia, there is muscular weakness and hyperæsthesia—particularly of leg and thigh muscles, there is absence of knee-jerks, there is probably a cardiac bruit and reduplication of sounds, and there are signs of dilatation of the heart and relaxed arterial tension. Just as in the other cases, the general health of the patient is unaffected, the tongue is clean, the urine though scanty is otherwise normal, and there is no fever.

Great variety in degree and combination of symptoms. — All through the wards of the hospital similar cases may be encountered. Some are so trifling that they are up and moving about with more or less freedom; and others are so severely smitten that they lie like logs in their beds, unable to move a limb or perhaps even a finger. Some are atrophied to skeletons; others are swollen out with dropsy; and some show just sufficient dropsy to conceal the atrophy the muscles have undergone. Although the cranial nerves above the seventh are very rarely involved, in some it will be noticed that the laryngeal muscles are paralysed, the patient being unable to speak above a whisper or to produce an explosive cough. In one or two cases the

abdominal and the perineal muscles may be so profoundly paralysed that, when cough is attempted, at most a husky expiration is produced, whilst the belly is bulged forwards and the perineum shot downwards by the sudden contraction of the muscles of expiration. In practically all cases of over a fortnight's standing the knee-jerk and tendo-Achillis reflex are absent; at the very commencement of the disease these deep reflexes are exaggerated, gradually disappearing as symptoms develop, not to reappear for months, perhaps, after the patient is well in all other respects.

Erroneous diagnoses.—The novice in tropical medicine will be greatly puzzled for a time over these cases. I have seen them called cardiac disease, locomotor ataxia, muscular rheumatism, progressive muscular atrophy, ascending spinal paralysis, and have over and over again seen them relegated to that refuge for ignorance—malaria, and called "malarial rheumatism," or "malarial paralysis," or, more pedantically, "malarial paraplegia," or "malarial neuritis." *

If the visitor has the curiosity to examine the blood of these patients, possibly in a proportion of them he will find microfilariæ; very likely he will then think that the cases are forms of filariasis, and he may construct theories to explain how the filaria produces the symptoms. Or, if he examine the fæces, very probably in over 50 per cent. of the cases, or, in some countries, in nearly all the cases, he will find the ova of *Ankylostomum duodenale* and, probably, those of *Trichocephalus dispar* also. On this evidence he may conclude that these are cases of ankylostomiasis. He had better, however, not commit himself to such a diagnosis until he has ascertained how it fares with the rest of the population as regards these parasites; for he will find that the filaria, the

* Dr. Strachan has described (*Practitioner*, 1897, p. 477) a form of multiple peripheral neuritis which he calls "malarial." The disease is endemic, and very common in Jamaica. It differs from beriberi inasmuch as it is not attended with œdema, is frequently attended with implication of the cranial nerves, and is rarely fatal. We have no accounts of any similar disease from other tropical countries. Probably, therefore, Dr. Strachan's neuritis is not malarial, but depends on some cause peculiar, so far as known, to Jamaica. The subject requires further study.

ankylostomum, and the trichocephalus are quite as prevalent outside as inside the hospital, and in the healthy as in the sick.

Past history of patients.—On inquiry he will learn that most of the cases come from two or three centres where similar disease is endemic—from some particular institution, plantation, mine, or village. He will also remark that the same places supply both atrophic-paralytic cases and dropsical-paralytic cases; and he will also learn that many of the atrophic cases commenced with dropsical symptoms. From this he will make the important deduction that he is dealing, not with two diseases, but with two phases of the same disease, which sometimes assumes atrophic features, sometimes dropsical features, and sometimes is of a mixed character. Some of the patients will give a history of fever at the outset of their troubles; in some there is a history of indigestion or diarrhœa; in some the paralytic or dropsical symptoms developed very slowly; in others, again, they came on rapidly. In some there is a history of a similar attack the previous year, or a yearly attack for three or four years in succession. Some will tell that they have been ill for several months, others that they have been ill for a week or two only.

Uncertain course.—The visitor will learn that this disease, which is beriberi, slowly or rapidly declares itself after an incubation period as yet undetermined but variously stated as of weeks or months, that it may be preceded by a period of intermitting languor, aching legs, palpitations, breathlessness, slowly advancing œdema of legs or face; or that the patient may wake up some morning and find that during the night he has become dropsical or paretic. Thus the disease may develop slowly or rapidly. Equally uncertain are its progress and danger; within a day or a week, or at any time during its course, it may assume fulminating, malignant characters. It may completely subside in a few days, or it may drag on for months. It may get well apparently and then relapse. It may, and generally does, clear up completely; or it may leave a dilated heart, or atrophied

limb muscles with corresponding deformity. The variety in the severity, progress, and duration of beriberi is infinite; but in all cases the essential symptoms are the same--greater or less œdema, especially over the shins; muscular feebleness and hyperæsthesia, especially of the legs; numbness, especially over the front of the shins, of the finger-tips, occasionally of the lips; liability to palpitation from cardiac dilatation, and to sudden death from the same cause.

Progress of the cases.—As the visitor watches the progress of the cases he will be astonished that those which he thought examples of locomotor ataxia, or of progressive muscular atrophy, or of ascending spinal paralysis, gradually improve, begin to walk about, and finally quit the hospital quite well. He will be astonished to see, after perhaps a profuse diuresis, the bloated carcass, that could hardly turn itself in bed, rapidly shrivel to little more than skin and bone, and assume all the appearances of the atrophic cases; and, later, perhaps after many months, become rehabilitated, and, in due course, walk out of the hospital quite well. He will notice that the cardiac bruits come and go; that the degree of dilatation of the heart is subject to fluctuations; that what seemed confirmed organic disease completely disappears.

Cardiac attacks.—But he will also be astonished, as he goes his rounds, to see so often empty beds where the day before lay men whom he considered by no means seriously ill—certainly not dying. Some day he will come on a patient, whom the previous day he thought to be by no means seriously ill, actually *in extremis*. The poor fellow is propped up in bed, he is struggling for breath, his face is purple, his eyes are starting out of his head, his whole attitude is expressive of the utmost distress; he has a horrible, tearing, boring, crushing pain under his sternum and in the epigastrium; the vessels of his neck are throbbing violently, but his pulse is quick, small, intermittent, and his extremities are cold. In a short time the patient is dead. Some of the fatal cases,

he will note, die quite suddenly as if from syncope; but most die in the distressing way described, evidently from paresis and over-distension of the right heart, complicated and aggravated by œdema of the lungs, or by diaphragmatic paralysis, by hydrothorax, or by hydropericardium.

Nomenclature and classification of beriberi.—For purposes of description, the paralytic-atrophic cases are designated "dry beriberi" or beriberia atrophica; the dropsical cases, "wet beriberi" or beriberia hydrops; and those in which there is a combination of both conditions, "mixed beriberi." Sometimes the cases are classified according to the rapidity of development and gravity of symptoms into acute or pernicious, subacute, and chronic. None of these classifications is good, seeing that they all refer to the same disease, and that one form may suddenly or more slowly merge into the other.

Hamilton Wright, who reported beriberi as a specific bacterial enteritis, running a definite course and producing a toxic neuritis comparable to that of diphtheria, classifies the cases as follows:—

Acute ...	Cardiac Motor Sensoro-motor or Vaso-motor	Beriberi.
Residual...	Cardiac Motor Sensoro-motor or Vaso-motor	Paralysis.

Etiology. *Sex, age, occupation, etc.*—Beriberi attacks both sexes. Although rare in childhood and extreme old age, it occurs at all ages,* its favourite age being from about 15 to 30. It affects rich as well as poor. It is confined to no particular trade or occupation. If anything, it has a predilection for those who lead a sedentary life and are much indoors, as students, prisoners, and the inmates of hospitals and

* The breast-fed child of a beriberic mother is apt to develop the disease. Hirota states that of 52 infants who suffered from beriberi while being wet-nursed by beriberic mothers 42 recovered, 5 died, 5 were not accounted for. In the cases which recovered the improvement set in at once on the children being weaned.

asylums. It is apt to attack pregnant or parturient females. It is quite as common in the strong and full-blooded as in the weak and anæmic.

Climatic conditions.—In countries in which there is a hot and cold season the epidemic outbreaks occur during the former, old cases improving and new cases ceasing to crop up during the winter. In countries which are hot all the year round beriberi may appear at any time; most frequently, however, in such climates it appears during the rains. Thus it resembles malaria in being fostered by damp, by high temperature and, it has been said, by its most often attacking those who sleep on or near the ground. As with malaria, though its explosion in any given individual residing in the endemic area may be solicited by fatigue, chill, privation, and other causes of physiological depression, it is not actually caused by such circumstances. Unlike malaria, it is common enough in the midst of large cities, as well as in villages and jungle lands.

Influence of overcrowding.—Overcrowding seems to favour the outbreak, or rather the spread, of beriberi. This has, perhaps, a good deal to do with its frequency and virulence in oriental gaols, schools, mining camps, plantation lines, armies, ships.

Ship beriberi.—Unlike malaria, beriberi is common in the native crews, more rarely, though occasionally, among the European officers and sailors, of ships on the high seas and far away from any recent telluric influence. The crowding in the damp forecastle and the exposure incident to a sailor's life seem to be among the reasons, though not the only ones, for ship beriberi. Thus, this form of the disease is often seen at the Seamen's Hospitals at the Albert Docks and Greenwich among the lascars and sidi-boys of steamers trading to India, the disease appearing perhaps months after the ships have left the East, sometimes even months after they have been lying in the London Docks. Some years ago a number of these cases were admitted to the Seamen's Hospital at the Albert Docks. I had the curiosity to visit one of the ships from which several of the patients had been brought. I went into

the forecastle. Although the weather was mild for Englishmen, it was evidently very cold for the half-clothed lascars. They had a fire blazing in their quarters, every door, scuttle, window, and ventilator of which they had carefully closed. The place was suffocatingly hot, damp, and redolent of steaming humanity. I do not know how many men had stowed themselves away with their dirty rags in this place, but there was a crowd of them. Several had symptoms of beriberi, and were in their bunks. After seeing the forecastle I was taken to a little dark cell, an oblong den with a couple of bunks one on top of the other, located somewhere in the neighbourhood of the keel. There was no light or obvious means of ventilation, and barely standing room. There I found three men sitting on the lowermost bunk, all of them suffering from severe beriberi. One of them, I afterwards heard, died before morning; the others were sent to hospital just in time, I believe, to save their lives. The fact is that some of these epidemics of ship beriberi occurring in cold climates are fostered, though they may be not caused, by the artificial conditions which the ignorant lascars are allowed to bring about. They feel the cold of the English climate so much that, on entering British seas, they try to keep their quarters warm by lighting fires and stopping up ventilators. By these means they create a hot, steamy atmosphere and a sodden state of the place they live and sleep in, which is a very good imitation of the tropical conditions in which beriberi is prone to develop. Although such unhygienic conditions favour the occurrence of beriberi, they do not suffice to produce it; as is proved by the well-authenticated circumstance that the disease is very common in the European crews of Swedish and Norwegian ships, which, as compared to British ships, are in far better sanitary condition, and yet beriberi is comparatively rare in the latter.

Asylum beriberi. — Not very long ago exactly similar conditions to those above described, and with similar results, were conduced to by similar circumstances in the Dublin lunatic asylum already alluded

to. This asylum, built for 1,000 inmates, had 1,500 crowded into it. Anyone who knows what the atmosphere of even a well-regulated and not over-crowded dormitory in a lunatic asylum is like can imagine what it becomes in warm weather, when three patients are lodged in a place barely sufficient for two. The heat, the breath vapour condensed and streaming down the walls, the effluvia from the patients, the closed doors, the barred windows, the want of air, and the damp conspire to reproduce the conditions found in the tropics; and it may be that when such conditions are reproduced elsewhere, even in temperate climates, the result will be just the same.

Although for a long time something had been known about the conditions predisposing to beriberi, it is only lately that anything like approximately accurate knowledge as to the *causa causans* of the disease has been attained. Many hypotheses had been advanced on the subject, some plausible enough if judged of in the light of the times, others manifestly absurd. It is unnecessary to refer at length to these exploded theories. Suffice it to say that their authors appear for the most part to have been dominated by the idea that for the production of a disease something in the nature of a germ or of a poison has to be introduced into the body; they overlooked the possibility of disease being brought about, not by the introduction of something foreign or abnormal to the body, but by the deprivation of something essential for its healthy nutrition. We now know that it is to the latter circumstance we have to look for the cause, or at least part of the cause of beriberi. Beriberi is a disease of "deficiency," to use the expression of Funk.

It is desirable, in view of the possibility of further discovery, somewhat to qualify this statement. It is just possible that the condition brought about by this deficiency merely predisposes to, or is necessary for the operation of something else, perhaps an unknown germ which in the absence of this deficiency would remain inoperative even if intro-

duced. Further, it may be that there are two or more diseases included under the term "beriberi," each of them acknowledging a different specific cause. Indeed there are not a few facts suggestive of such a possibility.

However this may be, thanks to the work of Eijkman, Braddon, Fraser and Stanton,* we now know that the beriberi of the Eastern Peninsula, of the Eastern Archipelago, of the Philippines, of China and Japan is a consequence of a diet into which over-milled rice enters as the principal element, that is rice from which the entire pericarp has been removed; and that in this pericarp there is a substance essential for the proper nutrition of the nervous system.

If a fowl be fed on *paddi* exclusively, that is rice from which the husk has not been removed, the fowl will thrive and very likely gain weight; but if it be fed on a diet exclusively of white rice, that is rice from which the pericarp has been completely re-

* Eijkman was among the first to show scientifically that beriberi was connected with a rice dietary. He showed that prisoners fed on red rice escaped beriberi, and that those fed on white rice were exceedingly prone to the disease. Braddon, fixing his attention on the remarkable and admitted fact that of the various races inhabiting the Malay peninsula the Chinese are infinitely the most subject, the Klings (an immigrant Indian race) infinitely the least subject to beriberi, came to the conclusion that the excessive liability of the one race and immunity of the other are attributable to the difference in the way in which their staple food—rice—is prepared for the market. The Klings live on what Braddon calls "cured rice," that is rice which when garnered, and before husking, is boiled and dried. The Chinese use "uncured rice," that is rice that is husked without preliminary boiling. Braddon held that rice (*paddi*) is liable in certain localities to be attacked by a germ which in its multiplication produces a toxin, and that this toxin, which is not destroyed by cooking, is the cause of beriberi. The germ is destroyed by the boiling to which "cured rice" is subjected before husking; hence the freedom of the Klings from beriberi and the excessive liability of the Chinese. That there is no racial insusceptibility in the Klings is proved by their being attacked by beriberi when they chance to get imprisoned and are placed on the same food as their Chinese fellow-prisoners. These views received support from a carefully conducted experiment by Fraser and Stanton, who fed a gang of coolies on cured rice and another gang on uncured rice, both sets of coolies being in other respects under apparently identical conditions, with the result that many of those on uncured rice sickened with beriberi, whilst those on cured rice escaped the disease.

moved, it will after a short time show signs of peripheral neuritis, lose weight, and, if the exclusive diet be persisted in, die with all the signs of a multiple peripheral neuritis. If a fowl which, in consequence of such a diet, has begun to show signs of peripheral neuritis be given regularly some of the polishings of the rice, that is the dust or remains of the pericarp, which had been removed in the process of milling, it will gradually lose the signs of neuritis, gain in weight, and recover. The neuritis—*polyneuritis gallinarum*, as it is called—is evidently the result of the deprivation of some element of food essential for the proper nutrition of the nervous system of the bird, and this element is located in the pericarp of the rice grain.

The polyneuritis of the fowl is identical clinically and etiologically with the polyneuritis, called beriberi, occurring in man. For, as has been both accidentally and intentionally done, if the same experiment with rice-feeding is tried on man the result has been identical—beriberi is induced. Thus, Strong and Crowell conducted a series of experiments on twenty-four life-sentenced prisoners, and were able to prove (*a*) the non-communicability of the disease and (*b*) its production in man solely by means of diet.

Fraser and Stanton showed, and their observations have been abundantly confirmed, that the antineuritic element is located in the pericarp of the rice grain, that it is soluble in alcohol, is stable in acid but unstable in alkaline solutions, is thermolabile —being destroyed by a temperature of 130° C.—and that it is dialysable; that it is not a phytin nor a fat, and that, although itself not containing phosphorus, the amount of phosphorus in any given rice is a reliable indication of the safety, or otherwise, of that rice as a staple article of food. Rice containing less than 4 per cent. of P_2O_5 they consider unsafe, and believe that its persistent use may lead to beriberi.

Acting on these findings, the Governments of Singapore and the Federated Malay States interdicted the use of white or polished rice in their goals, lunatic asylums, schools, and hospitals, with

the result that beriberi, which hitherto had been the cause of an enormous mortality and morbidity, has been practically banished from these institutions. Corresponding results have accrued from the same practice in Dutch Malaya, in the Philippines, and elsewhere.

It has been proved by Funk and others that the same or a similar antineuritic body is present in other cereals and in a variety of food-stuffs. It seems probable that the destruction by heat in the process of canning, or otherwise, of this body, called by Funk "vitamine"*—which exercises a curative as well as a protective action—may account for the prevalence of ship beriberi in Scandinavian ships, especially in long voyages during which such foods are an unavoidable necessity. In this respect there is a parallelism between beriberi and scurvy.

Morbid anatomy and pathology.—There is very little to be said about the post-mortem appearances in beriberi which is not covered by the accepted descriptions of the lesions of peripheral neuritis. There is a degeneration of the peripheral nerves—more especially of their distal ends, and there is secondary atrophic degeneration of muscle, including that of the heart, which may be the subject of an acute fatty degeneration like that of diphtheria. Hamilton Wright has recently shown that degenerative nerve changes (formerly denied) may be detected in the nerve centres and throughout the implicated neurons, as in other forms of peripheral neuritis. This observer seeks to correlate the early or "acute" phase of the disease with the primary poisoning of the nerve-endings, the latter or "residual" phase with the stage of nerve degeneration. If there is anything peculiar about the post-mortem appearances in beriberi, it arises from the somewhat special implication of the central and peripheral organs of the circulation—namely, dilatation of the heart, especially of the right side, and great accumulation of blood in the right heart and in the veins. In addition, there is a marked liability in many cases to serous effusion into the pericardium, pleural cavities, peritoneum, and cellular tissue. This very marked liability to serous effusion, and the tendency to cardiac dilatation, may be said to be more or less distinctive of beriberic as compared with other forms of multiple neuritis. The type of œdema indicates that it depends especially on vaso-motor disturbances, although cardiac weakness and partial suppression of urine may be contributory elements. Œdema of the lungs also is not uncommon, and has, probably, a pathology similar

* "Vitamine" is a body allied to allantoin.

to that of the connective-tissue œdema. There is no nephritis. The only lesion that might be considered specific in beriberi is the duodenitis, which, according to Hamilton Wright, is invariably present in acute cases during the first three weeks of the disease. The invariableness of this lesion is denied by other observers—Daniels, Koch, and Hunter.

Mode of death.—The most practically important point in the pathology of beriberi is that which relates to the modes of death. The paresis and the atrophy of the voluntary muscles, the œdema of the connective tissue, and the serous effusions are, as a rule, not very serious matters—at all events as affecting life. But it is very different when paresis and degeneration seriously implicate the heart and the muscles of respiration. In nearly all beriberies there is heart trouble, arising, doubtless, from implication of the pneumogastric nerve and the cardiac plexus. In some patients the degree of implication is slight; but in others it is sufficient so to weaken the heart that death is inevitable. We cannot be quite sure in which cases the implication of the pneumogastric nerve or cardiac plexus is likely to be serious, or in which cases it is likely to be slight. Often the mildest cases of beriberi, as judged by the degree of voluntary muscle paresis or by the amount of œdema, are in reality the most dangerous. There appears to be an element of chance determining the nerves which the poison picks out. Sometimes one may see a case which is completely paralysed so far as legs and arms are concerned, and perhaps wasted to a skeleton; and yet this same patient may never have a serious symptom referable to his heart, or in any way threatening life. On the other hand, one may see a patient with very little paresis, very little œdema, and yet in a short time the heart may become involved, and he will die in a few minutes or hours.

I presume the dilatation of the heart, the usual cause of death, is favoured or brought about by a concatenation of several conditions: by degeneration of muscle fibre following nerve destruction, by imperfect systole in consequence of an interrupted nerve supply, by obstruction to capillary circulation in consequence of vaso-motor paresis in the pulmonary

and general circulation. Once commenced, the cardiac dilatation tends to increase automatically; for the more the organ dilates the more difficult does it become for it to contract, the greater is the incompetency of the valves, and the more the blood stagnates in and over-distends it. The organ enters on a vicious pathological circle. Finally it becomes so distended that, like an overstretched bladder, it loses the power to contract altogether. The blood then rapidly accumulates in the great veins, the right auricle and ventricle are distended almost to bursting, and death is inevitable. The result is often contributed to by the coexistence of pleural effusion, hydropericardium, paresis of the diaphragm, over-distension of the stomach by food or gas, and, above all, by œdema of the lungs. It can readily be understood how the establishment of any additional obstruction of this description would still further tax the dilated, enfeebled heart and determine the fatal issue.

When we come to make a post-mortem in these cases we may find a heart slightly hypertrophied and enormously dilated, the right cavities distended with blood, the lungs and liver full of dark blood, and all the great veins engorged.

Prognosis.—This tendency to dilatation of the heart is the dangerous element in beriberi; it should always be before our eyes, and dominate our plans of treatment. It is wonderful how rapidly it may come on, and how rapidly it may prove fatal. These sudden deaths, occurring sometimes from syncope—from instantaneous failure, as well as from the somewhat slower process of increasing over-distension—are constantly sprung on one in this disease. An absolutely favourable prognosis, therefore, ought never to be ventured on in even the mildest-looking case of beriberi, or so long as the patient is exposed to the conditions causing the disease, or so long as the neuritis appears to be active. That is a lesson which is often, and sometimes painfully, borne in on the practitioner in beriberi districts.

Evidences of grave heart implication, such as pulsating cervical vessels, equal spacing of the inter-

vals audible on auscultation, enlargement of cardiac dullness especially to the right, epigastric pulsation, a rapid feeble pulse, a distended stomach, cold extremities, cyanosis, dyspnœa, and a disproportion in the strength of the heart- and wrist-beats, are significant of danger. *Paralysis of the diaphragm, of the intercostal muscles, extensive serous effusions, very scanty urine* are also unfavourable signs.

Vomiting.—No one can say when or how soon fatal implication of the pneumogastric and other cardiac nerves may take place, but vomiting is always an ugly and threatening symptom in beriberi; it probably indicates that the former important nerve is being attacked. The Japanese regard the occurrence of vomiting as of fatal import. Marked dilatation of the stomach has a similar significance.

Prognosis is improved if the patient is placed on a non-beriberic diet and is removed (that is before the heart muscle, or the cardiac or respiratory nerves, are gravely degenerated) from the place in which the disease was contracted, to a healthy, non-beriberic, high-lying locality.

Mortality.—The mortality in beriberi varies in different epidemics and in different localities. On the whole, it is greater in low than in high latitudes, in the dropsical than in the atrophic forms, in the acute than in the chronic. In some epidemics it is as high as 30 per cent. of those attacked; in others as low as 5 per cent., or even lower.

Diagnosis.—Usually the diagnosis of beriberi is not difficult. Multiple peripheral neuritis occurring as an epidemic, or in a place or ship in which the disease has occurred on some previous occasion, may as a rule be set down as beriberi. Sporadic cases may be difficult to diagnose, more especially if there is a history of alcoholism, malaria, or of drugging with arsenic. The presence, actual or past, of œdema—especially of œdema over the shins—and palpitations and other evidences of cardiac implication, are significant of beriberi. It must be borne in mind that slighter degrees of beriberic poisoning, evidenced only by slight anæsthesia of the

pretibial skin area, by slight œdema of the same region, by slight hyperæsthesia of the calf muscles, and, perhaps, by impairment or absence of knee-jerk, may be the only symptoms present. True rheumatism is rare in the tropics. Among natives, especially if their language is not understood, complaints of what may seem to be rheumatic pains in the legs should always be carefully investigated, the knee-jerks tested, and signs of hyperæsthesia of the calf muscles sought for. The significance of these signs of what may be described as larval beriberi is too frequently overlooked until some sudden death, which, with earlier recognition of the disease, might have been avoided, puts the practitioner on his guard. All paretic affections, all cases of œdema, all cases of palpitation, and all cases of rheumatic-like pains occurring among the natives of warm climates, therefore, should suggest the possibility of their being beriberic, and also the necessity for a detailed examination with this in view.

Treatment.—The first and most important thing to be attended to in the treatment of a case of beriberi is the diet; from this rice, especially white rice, should be eliminated, and some article rich in vitamine—such as beans, peas, peanuts, wheaten flour (not over-milled), or oatmeal—substituted, and, in view of the fact that we as yet cannot be certain that beriberi is not in some way dependent on an unknown germ, the patient should be removed, if practicable, to some place away from the endemic spot, to some dry locality, if such is available. He should sleep well off the ground in a thoroughly ventilated, sunny room situated in an upper storey. He ought to clothe sufficiently and feed well, taking care that the food is not of a bulky character, and that it contains a sufficiency of nitrogenous and fatty elements. Apart from other considerations, rice is found to be a bad food for beriberics; it is too bulky. Animal food, including fat, must enter into the dietary in reasonable amount. Milk and eggs are beneficial. Yeast is credited with curative properties, and extracts of rice-polishings, prepared in various

ways, have undoubtedly a beneficial effect and, when procurable, ought to be given. The worst cases, particularly if there is any sign of serious cardiac implication, should remain in bed; but the mild cases had better spend the greater part of the day in the open air. If the disease break out on shipboard the dietary should be changed and the crew should be kept out of the forecastle, and, so far as possible, made to sleep on deck, properly protected from the weather by an awning.

With a view to diminishing to some extent the bulk of blood in the vessels and heart, the seriously affected patients should take little fluid, and keep the bowels free by some saline aperient. In cardiac cases small doses of digitalis or of strophanthus seem to do good. Should signs of acute cardiac distress appear, full doses—three, four, or five drops of the 1 per cent. solution—of nitro-glycerine are indicated. The dose must be repeated every quarter- or half-hour, and kept up until the threatening symptoms pass away. In suddenly developed cardiac attacks inhalations of nitrite of amyl, pending the operation of the nitro-glycerine, may be given. It is well for these two drugs to be in the hands of properly instructed ward attendants, so as to meet cardiac complication on its earliest appearance. There is often no time to send for the doctor. Should signs of cardiac distension and failure persist and increase in spite of these means, there must be no hesitation in bleeding the patient, taking, if it will flow, eight or ten ounces from the arm, or, this failing for any reason, from the external jugular. Often, as the blood flows, rapid amelioration of the alarming condition sets in, and the patient is, for the time being, tided over an acute danger and given another chance. The bleeding should be repeated if the alarming symptoms recur, as they are almost sure to do. Oxygen inhalations, if available, are worth trying in cardiac attacks. Pleural and pericardial effusions should be sought for, and, if deemed to be interfering in the slightest degree with the circulation or respiration, drawn off with the aspirator.

Provided the patient is placed on a suitable diet and has been removed from the spot where he fell ill, and provided he can be tided over the first fortnight, he will probably recover; but, on the other hand, should he persist in a diet of white rice and remain in the place where his disease was acquired, though he may get over one or two cardiac attacks, he will almost surely die.

For the atrophy of the muscles and anæsthesia of the skin, faradisation and massage are of service, and should be employed so soon as the muscular hyperæsthesia has begun to subside. Strychnine, arsenic, and nitrate of silver are in repute as tonics in these circumstances. Care should be taken that permanent deformity does not occur from contraction of muscles. Foot-drop should be counteracted by Phelps's talipes splint with an elastic accumulator, and any other threatened deformity appropriately met. Relapses must not be risked by a return to the original diet or source of infection. The seaside or a sea-voyage has often a marvellously restorative effect.

When beriberi breaks out in a school, gaol, or similar institution the place should be emptied of its inmates as soon as possible; at all events, those parts of the building in which the disease has appeared ought to be cleared out, and not reoccupied until they have been thoroughly cleansed, disinfected, ventilated, and dried. Overcrowding must be strictly avoided. Ventilation must be effective. The dietary should be revised and, if necessary, have rice eliminated; in the place of rice, meat, flour, or beans should be substituted. All the inmates should be obliged to pass the larger part of every day in the open air; their knee-jerks should be tested, and their legs examined for numbness, œdema, and muscular hyperæsthesia from time to time. Any suspicious case should be removed at once.

Should beriberi appear on board ship, besides the precautions already indicated, on the assumption that there may be an infective as well as a dietetic element at the bottom of the disease, special means of disinfection must be employed. Rotten planking and

bilge-water must be removed from the neighbourhood of the quarters of the crew; the sound woodwork should be scraped and painted; disinfectants should be freely and frequently employed, clothes and sea-chests washed and disinfected, and every means necessary to destroy lurking germs vigorously adopted.

In beriberi countries low-lying, damp situations should be avoided as building sites. The sleeping quarters, especially, should be raised well off the ground, and located, if possible, in an upper storey; all rooms should be so arranged as to be easily flushed with fresh air and flooded with sunlight.

As yet we know little of the virus of beriberi, if such there be, nor is our knowledge of the way in which it is acquired by any means complete. It may be communicable, and until we have more precise knowledge it is unjustifiable not to recognize the subjects of the disease as being possible sources of danger to others. Therefore, in the endemic zone, beriberics should be treated as infective and isolated. In gaols and similar institutions new-comers, whether manifestly suffering from beriberi or not, should be isolated and kept under special observation for a time, their clothes disinfected and body vermin scrupulously destroyed. Prison clothes and prison blankets especially should always be disinfected before being passed into store and before being served out. The utmost care should be exercised to keep prisoners free from vermin and the premises from flies, cockroaches, fleas, bugs and all insects that might possibly serve as transmitters of the hypothetical virus.

In institutions under Government control, or in conditions in which it can be successfully enforced, there should be a stringent rule against the use of over-milled rice. To legislate against the use of white rice in countries in which rice is the staple food would not be politic, and could only lead to opposition and defeat the object in view; but the authorities, by educative methods and in other ways, could do much gradually to eradicate any prejudice there may be amongst the natives against under-milled rice.

CHAPTER XXVI

EPIDEMIC DROPSY

Definition and description.—A specific, epidemic, perhaps communicable disease, running its course in from three to six weeks, and characterized by the sudden appearance of anasarca, preceded in most instances by fever, vomiting, diarrhœa, or by irritation of the skin, and often accompanied by a rash, by fever of a mild, remitting type, by disorder of the bowels, and by pronounced anæmia. The case mortality varies from 2 to 40 per cent., death being sudden and depending upon œdema of the lungs, hydrothorax, hydropericardium, or other pulmonary and cardiac complications.

History and geographical distribution.—The foregoing is a concise description, drawn principally from McLeod's account (*Trans. Epidem. Soc. Lond.*, N.S., vol. xii.) of a disease which appeared in Calcutta, it is believed for the first time, in the cold weather of 1877–78, of 1878–79, and 1879–80. On each occasion it disappeared with the advent of the hot weather. The same, or a similar, disease broke out at Shillong, Assam, 5,000 feet above the level of the sea, in October, 1878; at Dacca in January, 1879; at South Sylhet in the cold weather of 1878–79; and in Mauritius (Lovell and Davidson), having been imported from Calcutta, in November, 1878. There are no trustworthy accounts of its occurrence elsewhere, although certain vague statements seem to indicate that it appears at times in other parts of India. In Mauritius it prevailed until June, 1879, attacking about one-tenth part of the coolie population, of whom 729 died, a mortality of about 2 or 3 per cent. At Sylhet there were no deaths; at Shillong also the mortality was insignificant; but in Calcutta the death-rate in those attacked was

estimated as high as 20 to 40 per cent. Coolies and natives were alone affected; Europeans enjoyed a complete immunity. In Calcutta the disease was confined to a particular quarter; here it attacked families and groups of people, slowly extending its area, but at no time becoming generally epidemic throughout the city. A very limited epidemic of the disease appeared in Calcutta in 1901, and again in 1908–9.

Etiology.—Both sexes were attacked; children under puberty were less liable than adults; sucklings were seldom affected. The weak and the robust were equally susceptible. There are no direct observations on the germ of the disease; there is indirect evidence of its portability and of its communicability. But as to whether it is directly communicable from man to man, or whether it, or its cause, is indirectly transmitted through some unrecognized medium, has not been determined. Evidence of its capacity for remaining latent for a considerable period is supplied by the history of the successive epidemics in Calcutta, where it is said more especially to affect the Hindus. The disease could not have been a very catching one, seeing that no medical man was attacked, and that, except in the case of Mauritius, it spread but slowly.

Major Greig, who has made a special study of the disease during the epidemics in Calcutta, concludes that it is in some way connected with the consumption of damaged grain, and especially of rice. The nature of the disease is still obscure; many believe it to be nothing but beriberi, and it is possible that observers, while entertaining opposite opinions, have been dealing with two different diseases.

Identification.—McLeod, after a careful analysis of all the available evidence, concludes that epidemic dropsy is a disease *sui generis*. At the time of its occurrence in Calcutta many of the physicians there looked upon it as a form of beriberi; and, indeed, in many respects it resembles very closely those cases of beriberi in which dropsy is a prominent symptom, and in which the nervous phenomena are slight or

altogether absent. But in epidemics of beriberi such cases are the exception—in fact, are very rare, and always concur with others in which nerve symptoms are pronounced, and with purely atrophic cases; such were not seen in either the Calcutta or the Mauritius epidemics. In epidemic beriberi the mortality is much higher than in the Shillong or in the Sylhet epidemic. Furthermore, beriberi is a much more chronic disease, is not accompanied by an eruption, and but seldom with well-marked fever.

Special symptoms.—According to McLeod *dropsy* was almost invariably present. It usually appeared first in the legs, and in some instances was confined to the lower extremities; in others it spread and involved the entire body. Occasionally it was very persistent, lasting and recurring during convalescence.

Fever also was a very constant symptom; sometimes it preceded, sometimes it accompanied, sometimes it succeeded the dropsy. It was rarely high, ranging usually from 99° to 102° F.; in a few cases —possibly from malarial complications—it reached 104°. Rigors were rare.

Diarrhœa and *vomiting* generally ushered in the disease in the Mauritius epidemic. In Calcutta these symptoms were not so frequent, although they were by no means rare there, occurring at both the earlier and later stages. Dysentery was common in the Calcutta epidemic.

Nervous symptoms—such as burning, pricking, itching, and feelings of distension of the skin, sometimes limited to the soles and feet—often preceded the dropsy. Distressing aching of muscles, bones, and joints, worst at night, was usual. Anæsthesia of skin areas and paresis of muscles were never observed in Mauritius. Harvey remarked two cases in Calcutta exhibiting doubtful paretic symptoms; these are the only two recorded in which there was anything resembling the paretic symptoms usually so prominent a feature in beriberi.

An *exanthem*, erythematous on the face, rubeolar on the trunk and limbs, was frequently seen in

Mauritius, less frequently in Calcutta. It appeared about a week after the œdema, and lasted from ten to twelve days.

Circulation and respiration.—Disturbances of the heart and circulation were prominent features in nearly all the cases. The pulse was weak, often rapid and irregular; cardiac bruits were also noted. Breathlessness on exertion occurred in all cases; severe orthopnœa in many. Signs of pleural and pericardial effusion, of œdema of the lungs, of pneumonia, and of cardiac dilatation were common in Calcutta.

Anæmia was usually present and marked; so were wasting and prostration. Scorbutic symptoms occasionally showed themselves.

The *liver*, *spleen*, and *kidneys* were not specially affected. The urine was rarely albuminous.

Morbid anatomy.—Beyond general œdema and occasional pleural and pericardial effusion, nothing special was remarked post mortem.

Treatment.—In the absence of anything like precise knowledge of the cause and pathology of epidemic dropsy, treatment must be entirely symptomatic. Mild purgatives, the exhibition of digitalis when there is evidence of cardiac weakness, and the occasional use of the nitrites in the fits of orthopnœa might prove serviceable. During convalescence iron and arsenic are indicated.

CHAPTER XXVII

RAT-BITE DISEASE

Definition and description. — A disease, according to Hata, long known to Japanese physicians, but little known in Europe. It is characterized by a local disturbance at the site of inoculation, and by general fever which is often accompanied by a papular rash. The mortality is low, about 10 per cent. (Hata). The germ cause is unknown. The symptoms develop only in a certain proportion of those bitten by rats. The incubation period varies from five weeks to two months, during which time the wound heals.

Symptoms.—The site of the bite shows inflammatory changes, a process which may spread to surrounding tissues with formation of blebs and even necrotic areas; the lymphatic glands draining the area are also implicated. Symptoms such as are associated with absorption of a toxin make themselves evident—including rigors, headache, and fever (103°–104° F.). The fever lasts generally some three or four days and ends in crisis, after which the local inflammatory symptoms subside. A second attack of fever, associated with the same symptoms and in addition with a papular exanthem, generally occurs after the lapse of some days or even a week. Further recurrences are common, the temperature often becoming irregular.

In most cases the reflexes are increased; the liver and spleen are not enlarged. In severe cases pains in the muscles and joints, hyperæsthesia, and œdema of various portions of the body are a marked feature. The end is ushered in by delirium often lapsing into coma.

Treatment.—Hata reports that in eight cases intravenous injections of salvarsan were followed by marked improvement.

Section III.—ABDOMINAL DISEASES

CHAPTER XXVIII

CHOLERA

Definition.—An acute, infectious, epidemic disease, characterized by profuse purging and vomiting of a colourless serous material, muscular cramps, suppression of urine, algidity and collapse, the presence of a special bacterium in the intestine and intestinal discharges, and a high mortality.

History and geographical distribution.—It is probable that from remotest antiquity cholera has been endemic in Lower Bengal,* and that thence, from time to time, it has spread as an epidemic over the rest of India. European physicians observed it there in the sixteenth, seventeenth, and eighteenth centuries, but it was not until the great epidemic extension of 1817 that the disease seriously attracted the attention of the profession in Europe. In that year cholera began to spread all over Asia, extending eastwards as far as Pekin and Japan, southwards to Mauritius, and westwards to Syria and the eastern shores of the Caspian. Stopping short at Astrakhan in 1825, it did not on that occasion invade Europe.

European epidemics.—In 1830 cholera visited Europe for the first time. Advancing through Afghanistan and Persia, it entered by way of Russia, and swept as an epidemic over nearly the entire continent, reaching Britain at the beginning

* Though it is customary to speak of Lower Bengal as the home of cholera, it is by no means certain that other Eastern localities have not some claim to a similar distinction—Bangkok, Canton, and Shanghai, for example. Dr. Henderson, in his health reports, indicates that the disease is rarely absent during the summer months from the last-named city; the same may be said of Bangkok and of Canton.

of 1832. During the same summer it crossed the Atlantic to Canada and the United States. This epidemic did not die out in Europe till 1839. Since that time there have been at least five European epidemics—1848–51, 1851–55, 1865–74, 1884–86, and 1892–95. Minor epidemics have occurred in Europe since, but they have been restricted in area. The last, that during the Balkan War of 1913, did not extend beyond the seat of war.

Great Britain has been seriously involved in four only of these epidemics—namely, in 1832, 1848, 1854–55, and in 1866. On the occasion of the last two European epidemics, although the disease was frequently imported, it did not spread in Britain. America has not been so fortunate, for, although the 1870–73 epidemic practically spared Great Britain, it crossed the Atlantic and, entering by way of Jamaica and New Orleans, raged for a time in the United States.

From a study of the march of these various epidemics, it is to be concluded that cholera reaches Europe by three distinct routes: (1) via Afghanistan, Persia, the Caspian Sea, and the Volga valley; (2) via the Persian Gulf, Syria, Asia Minor, Turkey in Europe, and the Mediterranean; (3) via the Red Sea, Egypt, and the Mediterranean.

With certain exceptions, hereafter to be mentioned, there is hardly an important country in the world which has not, at one time or another, been visited by cholera in the course of some of its pandemic extensions.

Etiology. *The disease is carried by man.*—A study of the various epidemics shows that in its spread cholera follows the great routes of human intercourse, and that it is conveyed chiefly by man, probably in its principal extensions by man alone, from place to place. In Britain and the United States, for example, the places first attacked have been invariably seaports in direct and active communication with other ports already infected. In India, although the problem is much more difficult to unravel, in certain instances the influence of

human intercourse in diffusing the disease can be distinctly traced. Thus the extensive pilgrimages, so frequent in that country, are a fruitful source of its rapid spread. During these gatherings hundreds of thousands of human beings are collected together under highly insanitary conditions—as at the Hurdwar and Mecca pilgrimages. Cholera breaks out among the devotees, who, when they separate, carry the disease along with them as they proceed towards their homes, infecting the people of the places they pass through. Cholera never travels faster than a man can travel; but in modern times, owing to the increased speed of locomotion and the increased amount of travel, epidemics advance more rapidly and pursue a more erratic course than they did sixty years ago.

Isolation secures immunity. — In the case of isolated countries the absence of active and frequent intercourse with the outer world favours immunity, even during approximately pandemic extensions. Thus, though so near to the reputed home of cholera, the Andaman Islands have never been visited by that disease. Similarly, Australia and New Zealand hitherto have enjoyed practical exemption. The same can be said of the Pacific Islands, the Cape of Good Hope, the west coast of Africa, Orkney and Shetland, Iceland, the Faroe Islands, and many of the islands of the Atlantic.

Unequal diffusion in the endemic and epidemic areas.—Although cholera is always present in some part of the endemic area in Bengal, it is not equally diffused there, nor is it equally common at all seasons and every year. Thus, even within this area there are places which enjoy an absolute or a relative immunity, and there are seasons and years of special prevalence. It has also to be remarked that the season of immunity for one place may be the season for prevalence in another place, and vice versa. The same observations apply to the areas of epidemic extension.

When cholera extends as an epidemic, its course is often singularly erratic. Some places, apparently in the direct line of advance, are passed over, to

be attacked perhaps at a later period. Similarly, certain districts of a town may be spared, while other parts of the same town are ravaged by the disease.

Local conditions favouring the presence of cholera.—On the whole, it may be said that low-lying districts, particularly those along river banks, are more subject to the disease than high and dry situations; and that overcrowding and unhygienic conditions generally conduce to its prevalence. The principal and special element, however, which determines the diffusion of cholera is, undoubtedly, the character of the water supply.

Cholera in the main a water-borne disease, entering by the stomach.—From time to time many theories of the cause and nature of cholera have been put forward, most of them very absurd and manifestly incorrect. Most of these have now been definitely abandoned in favour of the theory that the cause of cholera is a specific germ which, in the main, is water-borne. The evidence in favour of this view may be regarded as being almost conclusive, although there is still some room for doubting whether the germ itself has really been discovered.

The earliest, and still one of the most telling pieces of evidence in favour of the water-borne theory of the diffusion of cholera, we owe to the late Dr. Snow. In August, 1854, cholera was epidemic in parts of London, notably in the neighbourhood of St. Anne's, Golden Square. A child, after an illness of three or four days, died of the disease at 40, Broad Street, on the 2nd of September. The discharges from the patient had been thrown into a leaky cesspool which, as was subsequently discovered, drained into a well only three feet away. This well supplied the neighbourhood with drinking-water. On the night of the 31st of August cholera broke out among those who used the water of this particular well, very few escaping an attack. On the 2nd of September a lady died of cholera at Hampstead. Attention was specially called to this lady's case, as hitherto the disease had not been seen in that district. On inquiry it was found that she had been habitually

supplied with drinking-water from the Broad Street well referred to, as she had formerly resided in Broad Street, and had retained a liking for the water from this particular well. She drank some of the water which had been procured on the 31st of August, both on that day and again on the 1st of September. On the latter day she was seized with cholera. A niece, on a visit to this lady, also drank some of the same water; she, too, was attacked by cholera, and died. A servant also drank the water; although she suffered to some extent, she recovered. So far as could be ascertained by careful inquiry, these people had had no connection whatever with the cholera district except through the water fetched from this particular Broad Street well. Cholera, as mentioned, was not epidemic at Hampstead at the time. The inference that the germ had been conveyed in the polluted water is difficult to avoid.

Another remarkable illustration of the diffusion of the cholera germ by water is supplied by a recent epidemic in Hamburg. At the time the sanitary conditions under which the inhabitants of the contiguous cities of Hamburg, Altona, and Wandsbeck lived were practically identical, save in the matter of water supply. Hamburg and Altona both drew their water from the Elbe; but, whereas the water distributed to the people of Altona was most carefully filtered, that supplied to the people of Hamburg was simply pumped up from the river and passed directly into the mains without filtration or purification of any description. The Wandsbeck water came from a lake, and was filtered. In Hamburg, during the epidemic, there were 8,605 deaths from cholera, equal to 13·4 per thousand; whereas in Altona only 328 deaths occurred, equal to 2·1 per thousand. The death-rate in Wandsbeck was similar to that of Altona. Hamburg and Altona are contiguous, and practically one city. At one part a street forms the boundary between the municipalities. On one side of this street, the Hamburg side, there were numerous cases of cholera; on the Altona side there were no cases. The houses on both sides of the street were of the

same character and occupied by the same class of people. The only difference, so far as could be ascertained, was in the water supply: the houses on the healthy side of the street received Altona water; those on the cholera-stricken side, Hamburg water. It was remarked that a certain group of houses on the Hamburg side remained free from the disease. On investigation it was found that, unlike the other houses on the same side, these houses derived their water supply from an Altona main.

As regards its relation to the water supply, this Hamburg epidemic is the exact counterpart of what happened in South London in 1854. Formerly this district was supplied with water by two companies—the Southwark and Vauxhall Company and the Lambeth Company. Both companies drew their water from the Thames—the latter from near Hungerford Bridge, the former from near Battersea Fields. The epidemic of cholera which visited London in 1849 was especially severe in South London. Subsequently the Lambeth Company removed its intake higher up the river to Thames Ditton, and consequently the water it supplied at the time of the 1854 epidemic had improved in quality. The Southwark and Vauxhall Company did not change their intake, and in 1854 they were still drawing their supply from the river near Battersea Fields. When cholera visited London in that year the death-rate from the disease in the houses supplied by the Southwark and Vauxhall Company amounted to 153 per 10,000 inhabitants, whereas that in houses supplied by the Lambeth Company was only 26 per 10,000. The mains of the two companies ran side by side, some houses receiving the water of one company, some that of the other.

During the Hamburg epidemic it was also found that the incidence of cholera was three times greater among those who used the town water than among those who got their supplies from wells. These, and many similar facts which might be adduced, clearly point to water as a principal medium for the diffusion of the cholera germ.

The virus contained in the dejecta.—Evidence equally conclusive tends to show that the germ on being swallowed by man multiplies in his alimentary canal, and, on being voided in the dejecta, subsequently finds its way by a route more or less direct to water again, in which, under favourable conditions, it continues still further to multiply. An illustration, amounting almost to proof, of the fact that the germ of cholera is contained in the stools of cholera patients is supplied by Macnamara. Some of the characteristic rice-water discharge from a cholera patient got mixed accidentally with a few gallons of water. This was exposed to the sun for twelve hours. Early the following morning 19 persons each drank about an ounce of the mixture. Within thirty-six hours 5 of these 19 persons were seized with cholera.

Conditions of infection are complex.—It is evident that the ingestion of the germ is a necessary condition for the production of the disease, but there are many facts which render it equally evident that this is not the only condition. Were it the only condition, then every one of those individuals referred to by Macnamara would have sickened. What the other necessary conditions may be it is, in the present state of knowledge, impossible to say.

There is reason to believe that not only are the conditions complicated as regards the susceptibility of the individual, but also that they are equally complex as regards the germ itself in relation to its pathogenic, proliferating, and diffusing properties.

The germ of cholera. *Early views.*—Since European pathologists first directed their attention to the subject, many views have been entertained as to the exact nature of the cause of cholera. Some of these views were of the most fantastic description. Mysterious atmospheric and telluric conditions were invoked, and only a very few years ago superstitious notions worthy of the Middle Ages were freely ventilated, even in high places and by educated minds. Among those who ventured to formulate definite and more reasonable hypotheses some considered that

cholera, like the more familiar exanthematous fevers, was directly contagious. Others thought that it was not directly contagious, but that it was communicated by the evacuations of the sick after these evacuations had undergone some peculiar fermentation process outside the human body. Others, again, as von Pettenkofer, regarded the virus as a chemical ferment which developed in the soil under certain unknown epidemic conditions.

*Discovery of the comma bacillus.**—Since the rise of the germ theory of infective disease most of these speculations have been definitely abandoned, or have received more precise expression in the view that cholera is caused by a certain bacterium, known as the comma bacillus or cholera vibrio, which Koch found to be present, practically invariably, in the stools and intestinal contents of cholera patients. This bacterium Koch first discovered in Egypt in 1883. Believing in its importance, he afterwards proceeded to India on a special mission, and there, in Calcutta, in 1884, he found the same bacterium in the intestinal contents of 42 fatal cases, and in the stools of 30 other cholera patients; in fact, he found it in every case of the disease examined. Moreover, he entirely failed to find it in any other disease or in healthy discharges. These observations, so far as they concern the presence of the comma bacillus in cholera stools, have been abundantly confirmed by many other workers; so that the presence or absence of this bacterium is now regarded as a trustworthy and valuable practical test of the choleraic or non-choleraic nature of any given case of intestinal flux; and this even by the opponents of Koch's special view as to the nature of the relationship of the bacterium in question to the disease with which it is so intimately associated. If only on account of its diagnostic value, the comma bacillus, therefore, is an organism of importance; but as many high authorities regard it as a necessary concomitant and even as the actual germ and true cause of Asiatic

* "Bacillus" is a bad term for this organism, which is really a spirillum.

cholera, the vibrio acquires an importance of the first rank.

Description of the comma bacillus.—The comma bacillus (Fig. 77) is a very minute organism, 1·5 to 2 μ in length by 0·5 to 0·6 μ in diameter—about half the length and twice the thickness of the tubercle bacillus. It is generally slightly curved, like a comma; hence its name. After appropriate staining, at each end, or at one end only, flagella can be distinguished; sometimes one, some-

Fig. 77.—Cholera bacillus. Agar culture: 24 hours' growth. × 1000. (*Muir and Ritchie.*)

times (though less frequently) two. These flagella, though of considerable length—from one to five times that of the body of the bacterium—owing to their extreme tenuity are difficult to see in ordinary preparations. They are not always present during the entire life of the parasite. In virtue of this appendage the bacillus exhibits very active spirillum-like movements. The individual bacilli when stained show darker parts at the ends or at the centre, suggesting spore formation. Sometimes in cultivations two or more bacilli are united, in which case an S-shaped body is the result; or it may happen

1. It has been found that there are several bacilli with morphological and cultural characters closely resembling those of the cholera comma, notably the Finkler-Prior bacillus of cholera nostras, Lewis's saliva comma bacillus, many of the comma-shaped bacilli discovered by Cunningham, and certain species found in river water. Koch and others maintain that, though morphologically similar, as these various bacilli behave so differently from that of cholera in culture media, they must be considered as biologically specifically distinct from the latter.

2. Cultures of pure bacilli have many times been swallowed by way of experiment; yet, although in some instances diarrhœa with comma bacilli in the stools has resulted, in only a very few instances has true cholera been produced. On this account it is held by some that the comma bacillus cannot be regarded as the germ of cholera. Against this it is advanced that other factors must be present to ensure the induction of cholera by such experiments; for example, a suitable and peculiar condition of the body, possibly, as Buchner suggests, some second and as yet unknown micro-organism. Buchner accordingly regards cholera as the result of a mixed infection. It is to be presumed, therefore, that in the two or three instances in which cholera followed on the intentional or accidental ingestion of cultures of the cholera vibrio, these secondary but essential conditions were present. It must be remembered also, in assessing the value of negative feeding experiments, that the cholera vibrio, like other pathogenic bacteria, may lose through cultivation, or otherwise, its virulence while retaining its morphological and cultural qualities.

3. A few cases of what, from a clinical point of view, appears to be true cholera have been observed in which the most careful and prolonged bacteriological examinations failed to detect the comma bacillus. Therefore, it has been advanced, as cholera can occur without the comma bacillus, the comma bacillus cannot be the cause of cholera. Against this it has been said that these observations were

defective; that although the bacillus was not found, it by no means follows that the bacillus was not present at some time in the case.

4. The comma bacillus has been observed in the stools of individuals who did not at the time or afterwards suffer from cholera. To this it is answered that although one of the necessary conditions for the production of cholera was present, others, equally necessary, were absent. Possibly, as Pettenkofer remarked, for the production of an attack of cholera three things may be necessary, X, Y, and Z. The comma bacillus may be the X, but in the absence of the Y, certain local, and of the Z, certain personal conditions, disease does not result.

5. It has been found impossible by the administration of comma bacilli to produce in the lower animals true cholera, or any condition with clinical symptoms closely resembling cholera. Koch and others, in certain experiments on guineapigs, acting on the supposition that the acid in the stomach killed the bacillus, neutralized this by the administration of sodium carbonate, and paralysed the intestine by intraperitoneal injections of tincture of opium. In this way they claim to have succeeded in killing guineapigs with symptoms to a certain extent like those of cholera. There are many sources of fallacy in this experiment, as has been pointed out by Klein and others. Exactly similar results can be got by using the Finkler-Prior and other bacilli. The most promising experiments in this direction are those by Jablotny on the ground squirrel, *Spermophilus guttatus*. By administering to this animal comma cultures in alkaline media a disease in many respects like cholera was produced; and, in the intestines and discharges of the animals experimented on, cholera-like pathological changes were found, as well as comma bacilli.

Variability of the cholera microbe. — Bacteriological studies, always difficult, are extremely so in the case of the cholera microbe owing to its special liability to variation, both in its morphological and in its pathogenic characters. On this subject Haffkine remarks: "When the cholera bacillus was first

discovered its properties were described with extreme precision, which helped in concentrating for a long time all studies on well-defined and carefully chosen specimens. Little by little, as the field of observation grew larger, a number of varieties have been found with characteristics differing so largely as to annihilate almost completely the original description. When we open the intestine of deceased cholera patients and investigate the microbes there, the adopted methods will bring to the surface vibrios in which the external forms, instead of the characteristic comma or spirillum, will vary between a coccus and a straight thread; the number and disposition of the cilia, the secretion of acids, the form of growth in broth, will vary; instead of giving in gelatin a discrete and well-defined figure of liquefaction, the variation will extend from the complete loss of this property to a rapid dissolution of the whole medium; there will be varieties which grow luxuriantly in given media, and others which do not grow there at all; some will be phosphorescent in the dark, and others not; some will give the indol reaction, and others will be deprived of this property, —and so on. The first thing to be done is to select carefully among these the most typical specimens, rejecting the others, and then to try their pathogenic power. We shall find such a divergence in strength that the extreme forms will not be believed to be the cholera species. There will be commas deprived of any virulence demonstrable on animals, and others which will kill the most resistant species. Some will be fatal to a guineapig at a dose of $\frac{1}{100}$ of a culture tube, and others harmless in doses 500 times stronger. The average comma dies out when introduced under the skin of an adult animal; others will spread in the system and give rise to a fatal septicæmia. The ordinary comma will be without effect on birds; but several specimens have been isolated, and believed to be typical, which easily killed pigeons by hypodermic or intramuscular injection. I believe to be of great value the method worked out by Pfeiffer for comparing all such varieties with one selected as typical, which he employed for the preparation of an antitoxic

serum. This method will be found of efficient help in distinguishing specimens of the greatest affinity with the average cholera comma. But once such specimens are selected and their particular properties studied, they begin to change from the first day they are introduced into the laboratory, and no calculation based on these studies is possible. In a case quoted by M. Metchnikoff, the proportion of the initial power of the microbe, and the strength it showed at a later trial, was as 75 to 1, the microbe having gradually sunk to $\frac{1}{75}$ of its initial virulence." These remarks, by so great a master of the subject, whilst they indicate a way of reconciling many apparent discrepancies in matters of fact and differences in the conclusions arrived at by different bacteriologists, and whilst they indicate a key to many of the clinical features of cholera, teach us caution in accepting as proved the causal relationship of the cholera vibrio to the disease with which it is so invariably associated.

Symptoms.—An attack of cholera commences in one of two ways: either it may supervene in the course of what appears to be an ordinary case of diarrhœa, or it may come on suddenly and without any well-marked prodromal stage. During cholera epidemics diarrhœa is unusually prevalent. It is a common observation that at such times an attack of this latter nature, after a day or two, may assume the characters of true cholera. The preliminary looseness in such cases is called the "premonitory diarrhœa." Whether this looseness is specifically related to the subsequent attack, or is of an ordinary catarrhal or bilious type and acts simply by predisposing to the specific disease, has not been determined. Possibly, owing to a catarrhal condition—in itself non-specific—the resisting power of the mucous membrane is impaired; possibly, in diarrhœa, the large amount of fluid in the gut affords a favourable medium for the cholera germ to multiply in. Besides diarrhœa, other prodromata, such as languor, depression of spirits, noises in the ears, etc., are sometimes noted.

When true cholera sets in, profuse watery stools, painless or associated with griping, and at first fæcal in character, pour, one after the other, from the patient. Quickly the stools lose their fæcal character, becoming colourless or, rather, like thin rice water containing small white flocculi in suspension. Enormous quantities — pints — of this material are generally passed by the patient. Presently vomiting, also profuse, at first perhaps of food, but very soon of the same rice-water description, supervenes. Cramps of an agonizing character attack the extremities and abdomen; the implicated muscles stand out like rigid bars, or are thrown into lumps from the violence of the contractions. The patient may rapidly pass into a state of collapse. In consequence principally of the loss of fluid by the diarrhœa and vomiting, the soft parts shrink, the cheeks fall in, the nose becomes pinched and thin, the eyes sunken, and the skin of the fingers shrivelled like a washerwoman's. The surface of the body becomes cold, livid, and bedewed with a clammy sweat; the urine and bile are suppressed; respiration is rapid and shallow; the breath is cold and the voice is sunk to a whisper. The pulse soon becomes thready, weak, and rapid, and then, after coming and going and feebly fluttering, may disappear entirely. The surface temperature sinks several degrees below normal—to 93° or 94° F.; whilst that in the rectum may be several degrees above normal—101° to 105° F. The patient is now restless, tossing about uneasily, throwing his arms from side to side, feebly complaining of intense thirst and of a burning feeling in the chest, and racked with cramps. Although apathetic, the mind generally remains clear. In other instances the patient may wander or may pass into a comatose state.

This, the "algide stage" of cholera, may terminate in one of three ways—in death, in rapid convalescence, or in febrile reaction.

When death from collapse supervenes, it may do so at any time from two to thirty hours from the commencement of the seizure, usually in from ten to twelve. On the other hand, the gradual cessation of vomiting

and purging, the reappearance of the pulse at the wrist, and the return of some warmth to the surface may herald convalescence. In such a case, after many hours' absence, the secretion of urine returns, and in a few days the patient may be practically well again. Usually, however, a condition, known as the "stage of reaction," gradually supervenes on the algide stage.

Reaction; cholera typhoid.—When the patient enters on this stage the surface of the body becomes warmer, the pulse returns, the face fills out, restlessness disappears, urine may be secreted, and the motions diminish in number and amount, becoming bilious at the same time. Coincidently with the subsidence of the more urgent symptoms of the algide stage and this general improvement in the appearance of the patient, a febrile condition of greater or less severity may develop. Minor degrees of this reaction generally subside in a few hours; but in more severe cases the febrile state becomes aggravated, and a condition in many respects closely resembling typhoid fever, "cholera typhoid," ensues. This febrile or possibly typhoid state may last from four or five days to perhaps a fortnight or even longer. In severe cases the face is flushed, the tongue brown and dry, and there may be delirium of a low typhoid character with tremor and subsultus; or the patient may sink into a peculiar torpid condition. The motions are now either greenish or like pea-soup, and may contain a larger or smaller amount of blood; at the same time they are very offensive. The reappearance of urine may be delayed from two to six days; at first scanty, high-coloured, cloudy, albuminous, and containing casts, it gradually becomes more profuse, paler, and with less albumin. Though at first the urine is very deficient in urea, in uric acid, and in salts, later the quantity of these substances may exceed for a time the normal.

During the stage of reaction death may occur from a variety of complications; from pneumonia, from enteritis and diarrhœa, from asthenia, or from such effects of uræmic poisoning as coma and convulsions.

In cholera there is a considerable variety in the character of the symptoms and in their severity, both as regards individual cases and as regards different epidemics. It is generally stated that during an epidemic the earlier cases are the more severe, those occurring towards the end of the epidemic being on the whole milder.

Ambulatory cases occur during all epidemics. Such cases are characterized by diarrhœa and malaise merely; there is never complete suppression of urine, the diarrhœa never loses its bilious character, and it is not accompanied by cramps. The attack gradually subsides without developing a subsequent stage of reaction.

Cholerine.—In another set of cases the diarrhœa may be somewhat more acute, and the stools assume the well-known rice-water appearance; but the looseness soon ceases without leading to suppression of urine, or to algide symptoms, or even to very severe cramps, and without being followed by a stage of reaction. Such cases are sometimes designated "choleraic diarrhœa" or "cholerine."

Cholera sicca.—A very fatal type is that known as "cholera sicca." In these cases, though there is no, or very little, diarrhœa or vomiting, collapse sets in so rapidly that the patient is quickly overpowered as by an overwhelming dose of some poison, and dies in a few hours without purging or any attempt at reaction. At the post-mortem examination the rice-water material, so characteristic of cholera, though it may not have been voided during life, is found in abundance in the bowel. Other cases die suddenly from apnœa caused, apparently, either by coagula in the right heart, or by spasm of the pulmonary arterioles, the lungs refusing to transmit the thickened blood. In certain cases, after temporary improvement, relapse may occur and is nearly always fatal.

Hyperpyrexia is an occasional though rare occurrence in cholera. In such the axillary temperature may rise to 107° F., the rectal temperature perhaps to 109° F. These cases also are almost invariably fatal.

Sequelæ.—Cholera is apt to be followed by a variety of more or less important sequelæ, such as anæmia, mental and physical debility, insomnia, pyretic conditions, chronic enterocolitis, nephritis, different forms of pulmonary inflammation, parotitis apt to end in abscess, ulceration of the corneæ, bedsores, and gangrene of different parts of the body. Jaundice occurs at times, and is said to be of the gravest import. Pregnant women almost invariably miscarry, the fœtus showing evidences of cholera.

Morbid anatomy and pathology.—Rigor mortis occurs early and persists for a considerable time. Curious movements of the limbs may take place in consequence of post-mortem muscular contractions. On dissection the most characteristic pathological appearances in cholera are those connected with the circulation and with the intestinal tract.

If death have occurred during the algide stage, the surface presents the shrunken and livid appearance already described. On opening the body all the tissues are found to be abnormally dry. The muscles are dark and firm ; sometimes one or more of them are discovered to be ruptured—evidently from the violence of the cramps during life. The right side of the heart and systemic veins are full of dark, thick, and imperfectly coagulated blood, which tends to cling to the inner surface of the vessels. Fibrinous clots, extending into the vessels, may be found in the right heart. The lungs are usually anæmic, dry, and shrunken ; occasionally they may be congested and œdematous. The pulmonary arteries are distended with blood, the pulmonary veins empty. The liver is generally loaded with blood ; the gall-bladder full of bile ; the spleen small. Like all the other serous cavities, the peritoneum contains no fluid, its surface being dry and sticky. The outer surface of the bowel has generally a diffuse rosy red, occasionally an injected appearance. On opening the bowel it is found to contain a larger or smaller amount of the characteristic rice-water material, occasionally blood. The mucous membrane of the stomach and intestine is generally pinkish from congestion, or there may

be irregularly congested or arborescent patches of injection here and there throughout its extent. In addition, there may be seen smaller or larger points of ecchymosis in or under the mucous membrane. The changes in the alimentary canal are most marked at the lower end of the ileum, where Peyer's patches and the solitary glands may be seen to be congested and swollen. In some instances the bowel is pale throughout; in many the mucous membrane has a sodden, pulpy appearance from exfoliation of epithelium—possibly a post-mortem change; occasionally, especially towards the lower end of the ileum, a croupous exudation is met with. The mesenteric glands are congested. The superficial veins of the kidneys are full; the medullary portion is much congested, the cortical portion less so; the tubules are filled with granular matter; the epithelium is cloudy, granular, or fatty, and, at a later stage, may be shed. The bladder is empty and contracted. Nothing special is to be noted in the nervous system.

If death have occurred during the stage of reaction, the tissues are moist; the venous system is less congested; the lungs are probably congested and œdematous, perhaps inflamed. Very probably there are evidences of extensive enteritis.

Microscopical examination of the contents of the bowel during the acute stage of the disease discovers, in most instances, the comma bacillus. Usually it is in great abundance; occasionally in what is almost a pure culture. Sections of the intestine show the bacillus lying on and between the epithelial cells of the villi and glands. In no other organ or tissue of the body is the bacterium to be found. Therefore, assuming that the comma bacillus is the cause of cholera, we must conclude that the clinical phenomena are not the result of a septicæmia; but that they arise either from a local irritation produced by the bacillus, or from some toxin which it generates in the bowel and which is absorbed; or from a combination of these factors.

That the cholera vibrio is a powerful irritant is shown by the effect produced locally by a hypodermic

injection of a virulent culture. When so injected, not only does it give rise to local œdema, but, unless precautions are taken, it causes in certain animals necrosis of the tissues and ulceration at the seat of injection. It is conceivable, therefore, that when in the course of the naturally acquired disease the bacilli proliferate in the bowel they or their products act as an irritant to the mucous membrane, and so provoke the hypercatharsis and the consequent dehydration of the tissues which are the dominating features of the disease. On the other hand, the hypodermic injection of cholera vibrio cultures is followed by smart febrile movement lasting from one to three days, evidencing the presence of a febrogenic toxin capable of producing constitutional symptoms. This fact, together with the rapid and intense prostration which, in some instances of natural cholera, appears to be out of all proportion to the amount of catharsis present, suggests that the lethal effects of the vibrio are attributable not alone to the drain of fluid from the blood and tissues but also to the absorption of a cholera toxin from the intestine. It is somewhat strange, however, if this toxin be anything more than a subsidiary element in the production of the symptoms in most instances of the naturally acquired disease, that catharsis is not one of the effects of the hypodermic introduction of the vibrio, and that fever is not an earlier and more prominent symptom in natural cholera. The modern tendency is to regard the clinical phenomena as the result partly of local irritation and partly of toxæmia; variation in the proportional intensities of the different clinical elements depending on the degree of virulence of the particular strain of microbe introduced, and on the circumstances and idiosyncrasy of the patient.*

Diagnosis.—During the height of an epidemic the diagnosis of cholera is generally an easy matter; the profuse rice-water discharges, the collapse, the

* Metchnikoff, Roux, and Salembeni demonstrated the existence of a soluble cholera toxin by introducing collodion sacs (2-3 c.c. capacity) filled with cholera cultures into the peritoneal cavity of guineapigs. Macfadyen obtained a virulent endotoxin by triturating cultures in liquid air.

cold clammy skin, the cyanosis, the shrunken features, the shrivelled fingers and toes, the feeble, husky, hollow voice, the cold breath, the cramps, and the suppression of urine, together with the high rate of mortality, are generally sufficiently distinctive. But in the first cases of some outbreak of diarrhœa, which may or may not turn out to be cholera, and the true nature of which for obvious reasons it is of importance to determine, correct diagnosis, though urgently required, may not be so easily attained.

Symptoms resembling true cholera may supervene in the course of an ordinary severe diarrhœa, and are very usual in cholera nostras, in mushroom poisoning, in ptomaine poisoning, in the early stages of trichinosis, and in a certain type of pernicious malarial fever. In none of these, however, is the mortality so high as in cholera. It may be laid down, therefore, that epidemic diarrhœa attended by a case mortality of over 50 per cent. is cholera.

In other forms of diarrhœa it is rare for the stools to be persistently so absolutely devoid of biliary colouring matter as they are in cholera. A careful inspection of the stools sometimes yields valuable information in other ways. Thus, in mushroom poisoning fragments of the mushrooms which caused the catharsis may be seen; in trichinosis the microscope may detect the adult trichina. In choleraic malarial attacks the presence of the malaria parasite in the blood, the periodicity of the symptoms, their amenability to quinine, together with the character of the prevailing epidemic, generally combine to guide to a correct diagnosis.

The detection of the comma bacillus in the stools is now regarded as a positive indication of cholera. It would be rash, however, to affirm that a negative result from bacteriological examination of a single case is conclusive against its being cholera. Moreover, such examinations to be trustworthy have to be made by a skilled bacteriologist. According to Kanthack and Stephens, the following were the methods of bacteriological diagnosis practised by Klein during the threatened epidemic in 1893:—

Method 1.—A flake from the dejecta is placed in peptone broth and incubated at 37° C. In twenty-four hours an abundant crop of vibrios is found in the superficial layers of the broth. This pellicle consists of a practically pure culture, or, at any rate, is a culture which easily allows of pure sub-cultures being obtained.

Method 2.—A flake is placed in sterile salt solution or broth; it is shaken up, and from this gelatin or agar tubes are inoculated, and plates are made. In agar plates incubated at 37° C. numerous colonies may be found in twenty to thirty hours. In the gelatin plates, after two to three days' incubation at 20° to 22° C., numerous typical colonies can be got. (A more modern method which is very efficacious is Dieudonné's blood-alkali agar. Equal parts of defibrinated ox-blood and normal caustic soda solution are mixed with 70 c.c. of neutral peptone agar. On this medium few organisms other than the cholera vibrio develop.)*

Method 3.—A flake is placed directly into Dunham's peptone salt solution (1 per cent. peptone, 0·5 per cent. sodium chloride), or the Dunham's solution is inoculated after previous dilution of the material. The peptone solution, after six, eight, to ten hours' incubation at 37° C., shows a definite turbidity, due to the rapid growth of the comma bacilli; and the cholera-red reaction may be obtained, although not absolutely specific. For speedy diagnosis this method is most valuable; in six to twelve hours, or, at latest, in sixteen hours, comma bacilli can be found in the superficial layers of the peptone solution, so that in twenty-four hours pure cultures and the cholera-red reaction can be obtained in secondary peptone tubes. Also, a positive result may be obtained by this method in cases in which the microscopical examination has failed to give definite evidence of the presence of vibrios.

In addition to these methods the agglutination test is frequently employed. The serum of a rabbit immunized against a known cholera vibrio by frequent and massive intraperitoneal injections, and therefore having a high agglutinating power, affords a very rapid means of differentiation of pathogenic from non-pathogenic vibrios.

In case of doubt as to the identity of a suspected cholera vibrio, Pfeiffer's reaction might be employed with advantage. An emulsion of the organism, to which a small amount of the patient's serum had been added, is injected into the peritoneal cavity of a normal guinea-pig. Half to one hour later the peritoneal fluid is examined. If the case be one of cholera the bacteria will be found to be degenerated and mostly spherular.

* The cholera vibrio forms indol very rapidly and in considerable amount, reducing nitrates to nitrites, especially in peptone water. A few drops of pure sulphuric acid added to a peptone-water culture eight to twelve days old gives a pinkish colour, more intense according to the age of the culture. The coli group and other bacteria produce indol, but do not reduce nitrates to nitrites so readily; the presence of the latter is essential for the reaction.

The first two methods are applicable to those instances in which microscopical examination of the stools shows crowds of comma bacilli. Method 3 is specially applicable to those stools in which comma bacilli are in very small numbers.

Mortality.—The average case mortality in cholera amounts to about 50 per cent. Some epidemics are more deadly than others. As already mentioned, the mortality is greater at the earlier than at the later stages of an epidemic. To the old, the very young, the pregnant, the subjects of grave organic disease—particularly of the liver, kidneys, and heart—the dissipated, the under-fed, and the feeble, the danger is very great.

Quarantine prevention.—Theoretically, quarantine should be an efficient protection against the introduction of cholera into a community; practically, it has proved a failure. Unless they are stringent and thoroughly carried out, quarantine regulations can be of little use. Unfortunately, the temptation to evade such regulations is in proportion to their stringency. It is impossible to secure the absolute honesty and efficiency of every individual in a large body of men charged with the details of any system entailing great personal inconvenience and loss to travellers and merchants. Therefore, if the strength of the quarantine chain is to be measured by that of its weakest link, the chain must be weak indeed, as a very slight knowledge of human nature will lead us to suspect, and a very slight acquaintance with the working of quarantine as ordinarily practised will attest. Even if the utmost care, intelligence, and honesty succeed in excluding individuals actually suffering from cholera, or likely within a reasonable time to suffer from cholera, there is yet no guarantee that the germ of the disease may not be introduced. Koch and others have shown that sometimes the dejecta even of individuals apparently in good health and who have not suffered, or who may not subsequently suffer from choleraic disease, may yet contain, and for some time continue to contain, the cholera vibrio. In 271 fatal cases Greig

found the vibrio in the gall-bladder, a situation favouring persistence in the event of recovery. During the epidemic of 1911, in Naples, 10 per cent. of healthy contacts had cholera vibrios in their stools and continued to pass them for three to five days. If the cholera vibrio be the germ of cholera, then such healthy, vibrio-bearing individuals may well suffice to start an epidemic. It is impossible, short of absolute and complete isolation, for any practicable system of quarantine to deal efficiently with such cases.

So far from ordinary quarantine proving a defence against cholera, it may actually increase the risk of an epidemic. This it does by fostering a false sense of security, and so leading to neglect of those well-proved guarantors of the public health—domestic, municipal, and personal cleanliness, and a pure water and food supply.

The system to which Great Britain apparently owed her immunity during recent epidemics on the continent of Europe is a practicable and, in civilized conditions, an efficient one. Under this system only ships which were carrying or which had recently carried cholera patients were detained; and even these merely till they could be thoroughly disinfected. Thus inconvenience and loss to travellers and merchants were small, and the temptation to conceal cases of the disease or to evade regulations was proportionately minimized. Any cholera cases were isolated in suitable hospitals, the rest of the crew and passengers, although supervised for a time, being given free pratique. At the same time, attention was not diverted from the sanitation of towns, especially of seaports; this was the measure mainly relied on. Suspicious cases occurring on shore were at once reported to the sanitary authorities and promptly dealt with, fomites being destroyed or disinfected at as little cost and inconvenience to individuals as possible. Every endeavour was made to prevent fæcal contamination of the public water supply.

Of late years in India effort is being directed much on the same lines, attention being given to sanitation rather than to quarantine. During the

great religious festivals the sanitary condition of the devotees is looked after so far as practicable, special care being given to provide them with good drinking and bathing water. Many of the large Indian towns now enjoy an abundant and pure water supply; and civilized systems of night-soil conservancy and other important sanitary measures are being gradually introduced and, in the case of more than one great city, with the most gratifying results.

Among the troops in India, on the appearance of cholera in their neighbourhood, special protective measures are promptly instituted, elaborate directions having been drawn up for the guidance of medical officers. For an account of these regulations the reader is referred to the Annual Report of the Sanitary Commissioner with the Government of India for 1895, Appendix, p. 189.

Incubation period.—All quarantine and protective systems must take cognizance of the fact that, although cholera may declare itself within a few hours of exposure to infection, it may also do so at any time up to ten days thereafter; three to six days may be set down as the usual duration of the incubation period.

Anti-choleraic inoculations. — During an epidemic of cholera in Spain, in 1885, Ferran instituted a system of prophylactic inoculation. He injected hypodermically ordinary laboratory cultures of the cholera vibrio obtained directly from cholera corpses. No attempt was made to regulate or standardize in any way the virulence of the cultures. The results were not encouraging. As accidents were frequent, the Government put a stop to the practice.

In 1893 Haffkine, after elaborate experiments on the lower animals, commenced a system of anti-cholera vaccinations, using a pure virus of a fixed and known strength. This virus he prepared by passing the cholera vibrio through a series of guineapigs by means of intraperitoneal injections. In this way the microbes were increased in toxicity to a definite point beyond which their virulence could not be exalted. Cultures so prepared gave rise, when injected hypodermically, not only to a general but

also to a local reaction, the latter being so severe that it ordinarily ended in extensive sloughing and ulceration. To avoid this undesirable result, a milder vaccine was prepared by cultivating the strong vaccine in artificial media at a temperature of 39° C., and in an atmosphere kept constantly renewed. By first injecting under the skin of animals this milder vaccine it was found that such a measure of protection was conferred that subsequent injection of the strong virus was no longer followed by violent local reaction. Having satisfied himself that the subcutaneous injection of these two vaccines conferred immunity against the cholera vibrio in the lower animals, Haffkine, with the approval and aid of the Government, proceeded to use them in man on a large scale in India. Up to 1895, 70,000 injections of living cholera bacilli had been made in 43,179 individuals. In no instance did any bad result ensue. While admitting that the value of his method has not been fully proved, Haffkine claims that the results are sufficiently encouraging to justify a continuation of these inoculations on a larger scale.

The symptoms which these injections produce are fever, transient œdema and tenderness at the seat of injection, the first evidence of constitutional disturbance appearing from two to three hours after the injection is made. The fever and general indisposition last from twenty-four to thirty-six hours, the local symptoms gradually disappearing in from three to four days. The symptoms following the second injection—made from three to four days after the first—are generally more marked, but of shorter duration. The microbes injected die; it is the substances set free on their death which confer the immunity. It is found that carbolized cultures—that is, dead vibrios—produce the same immunizing and constitutional effects, though in a somewhat milder and probably less permanent degree. How long the immunity conferred by these injections endures has not been definitely settled.*

* For details of Haffkine's original methods and technique see the *Brit. Med. Journ.*, Feb. 4, 1893, and the *Indian Med. Gaz.*, Nov., 1896.

In consequence of an experiment on himself, Haffkine found that, although the virulent comma bacillus produced necrotic effects at the site of inoculation in guineapigs, it did not do so in man. Accordingly, he has abandoned his original method of a primary inoculation with an attenuated virus, and has since countenanced immediate inoculation with virulent, recently-isolated vibrios, without further preparation. According to Powell, the method is as follows :—

"The whole surface of agar in a sloped tube is inoculated with the comma and cultivated for twenty-four to thirty-six hours at a temperature of 40° C. The whole surface should then be covered with a uniform layer of growth. Sterilized water is then added to one-third the height of the agar, and the growth washed off and suspended in the water by rapidly rotating or shaking, till the surface of the agar is quite clear. Half a cubic centimetre, about nine minims, is the dose for an average adult."

Powell's results are highly favourable—namely, 198 cases of cholera with 124 deaths among 6,549 non-inoculated tea-garden coolies in Assam, against 27 cases and 14 deaths among 5,778 inoculated coolies. Had the incidence of cholera been the same in both classes, the inoculated would have had 174 instead of 27 cases, and 109 instead of 14 deaths. In 1912, 8,000 Europeans were inoculated in Batavia, and among these there was only one death from cholera as against 15 deaths amongst 2,700 uninoculated.

Personal prophylaxis.—During cholera epidemics great care should be exercised to preserve the general health ; at the same time, anything like panic or apprehension must be sedulously discouraged. Fatigue, chill, excess—particularly dietetic or alcoholic excess—are to be carefully avoided. Visits to cholera districts should be postponed if possible, seeing that the new-comer is specially liable to contract the disease. Unripe fruit, over-ripe fruit, shell-fish, food in a state of decomposition, and everything tending to upset the digestive organs and to cause intestinal catarrh are dangerous. Melons, cucumbers, and the like deserve the evil reputation they have acquired. Purgatives—particularly saline

purgatives—unless very specially indicated, should never be taken at these times. All drinking water, and all water in which dishes and everything used in the preparation and serving of food are washed, should be boiled. Filters — except perhaps the Pasteur-Chamberland filter—are not for the most part to be relied on; in many instances they are more likely to contaminate the water passed through them than to purify it. A good plan in a household, or in public institutions, is to provide for drinking purposes an abundant supply of weak tea or lemon decoction, the supply being renewed daily; such a plan ensures that the water used in the preparation of the drink has been boiled. All food should be protected from flies.

Diarrhœa occurring during cholera epidemics should be promptly and vigorously treated.

Treatment.—During cholera epidemics it is customary to establish depots where sedative and astringent remedies for the treatment of diarrhœa are dispensed gratuitously. Experience seems to encourage the belief that by such means incipient cholera may be aborted during the stage of premonitory diarrhœa. Of the various drugs used with this view, chlorodyne, or chlorodyne and brandy, is the most popular. Lead and opium pill; chalk, catechu and opium mixture; compound kino powder; aromatic powder of chalk and opium; a pill of opium, asafœtida and black pepper; dilute sulphuric acid and laudanum, are among the drugs more commonly employed for this purpose. Whether true cholera can be cut short in this way or not, it is certainly in the highest degree advisable at such a time to neglect no case of diarrhœa, but to insist on rest, warmth, and the greatest prudence in feeding in all cases of intestinal catarrh or irritation.

Many plans of treatment, based on theoretical considerations, have been advocated from time to time. The eliminative treatment advocated by Dr. George Johnson; the spinal ice-bag recommended by Chapman; various antiseptic methods directed to the destruction of the vibrio in the intestinal canal; drugs

designed to counteract the physiological effects of the cholera toxins, as chloroform, atropine, nitrite of amyl, and nitro-glycerine, may be mentioned as belonging to this category of remedies.

Practically, the only treatment of proved value in cholera is the purely symptomatic and expectant one. If our efforts have failed to counteract the premonitory diarrhœa, attention should be given to maintaining the patient in as favourable a condition as possible to struggle against the poison of the disease. He should be kept strictly in the horizontal position, in a warm bed, and in a well-ventilated but not too cold room. His thirst should be treated by sips of iced water or of soda-water, or champagne, or brandy and water. Copious draughts, as they are likely to provoke vomiting, are usually condemned. It does not follow from this that they are harmful; the emesis contributes to the elimination of germ and toxin. Cramps may be relieved by gentle frictions with the hand or with ginger-root, by a small hypodermic injection of morphia, or, these failing, by short chloroform inhalations. The surface of the body should be kept dry by wiping it with warm dry cloths, and the surface heat maintained by hot-water bottles or warmed bricks placed about the feet, legs, and flanks. The patient must not be allowed to get up to pass his stools; a warmed bed-pan should be provided for this purpose. All food should be withheld while the disease is active.

If the pulse fail or disappear at the wrist, stimulants by the mouth, or, if there is much vomiting and these do not appear to be absorbed, hypodermic injections of ether or brandy may be given. No improvement ensuing, intravenous or subcutaneous injection of normal saline fluid may be had recourse to. A suitable injection may be quickly prepared of common salt 60 gr., carbonate of soda 60 gr., boiled water 1 quart. Of this, from one to three quarts at a temperature of 100° F. may be slowly introduced by gravitation into a vein, the effect being carefully watched. The pulse can generally be quickly restored temporarily by this

means and life prolonged, possibly in a few instances saved; too often, however, the fluid so introduced rapidly escapes by the bowel, and collapse once more sets in. Dr. Cox, of Shanghai, has had some encouraging results from continuous, prolonged, slow, intravenous injection of saline fluid, the fluid gravitating from a vessel placed 2½ ft. above the level of the patient's arm. The flow is kept up for several hours, and as long as it is deemed that there is any risk of collapse.

Rogers has recently introduced a method of treating cholera by intravenous injection of hypertonic saline solution, which promises well. He claims that since the introduction of his method the case mortality from this disease in the Calcutta Medical College Hospital has been reduced from 59 to 32 per cent. The principle of the treatment is based on the fact that not only is the water content of the blood reduced by one-third to two-thirds, according to the severity of the case, but in addition there is a loss of the saline constituents. Hence the necessity for supplying the latter. His hypertonic solution is composed as follows: Sodium chloride, 120 gr.; potassium chloride, 6 gr.; calcium chloride, 4 gr.; sterilized water, 1 pint. This he introduces by means of a special stop-cocked cannula and transfusion bulb at the rate of not more than 4 oz. a minute, the flow being slowed down to 1 oz. if distress or headache supervene. At the same time he gives permanganate of potassium in solution or in pill by mouth up to 50 gr. a day—2 gr. every quarter of an hour for two hours, then every half-hour till the stools are coloured green. In suppression of urine, if the blood pressure is normal, isotonic solution should be used.

Other Indian practitioners claim to have got better results in suppression of urine from permanganate in adrenalin solution, the dose of the latter being 10 minims of a 1-in-10,000 solution every three hours.

During the stage of reaction, should purging persist, large doses of salicylate of bismuth with a little opium may prove of service. In these circum-

stances massive rectal injections of tannin 1 oz., gum arabic 1 oz., warm water 1 quart, are of use. If the secretion of urine is not quickly restored, large hot poultices over the loins, dry-cupping of the same region, and the judicious use of bland diluents should be had recourse to. Stimulating diuretics are dangerous. Retention of urine must be inquired about, and the region of the bladder frequently examined, and, if necessary, the catheter employed. In the event of constipation, purgatives must be eschewed and simple enemata alone used.

In cholera convalescents the diet for a time must be of the simplest and most digestible nature—diluted milk, barley-water or rice-water, thin broths, meat juice, and so forth—the return to ordinary food being effected with the greatest circumspection.

Cholera typhoid must be treated much as ordinary enteric fever.

Precautions.—It must never be forgotten by those responsible for the management of cholera cases that through their discharges such patients are a danger to the community, and that those discharges may contain the vibrio in some instances up to fifty days after the attack. The Bordet-Gengou reaction,* a complicated serum reaction, has been advantageously employed in the detection of these cholera carriers. Further, that though the germ dies in a few hours if dried, it preserves its vitality for many days if kept moist, as, for example, in damp, soiled linen; that it may live for months as a saprophyte in water or

* The Bordet-Gengou reaction is based on the fixation of the complement, using a culture of the vibrio as an antigen. The following mixtures are prepared in three test tubes: Nos. 1 and 2 contain 0·2 c.c. suspension of cholera vibrio, and 0·6 c.c. suspected person's serum (heated to 56° F. for half an hour), and 0·1 c.c. complement (guineapig's serum); tube 3, a similar mixture with the substitution of normal person's serum. These tubes are shaken and incubated for half an hour. Then 1 c.c. of mixture of a serum hæmolytic to sheep's corpuscles (heated to 56° F. for half an hour) and one volume of washed sheep's corpuscles. To tube 2 is added 0·1 c.c. of a mixture of two volumes of normal saline and one volume of washed sheep's corpuscles. Should the suspected serum be that of a cholera carrier, the complement in tube 1 will be fixed and no hæmolysis occur, whereas in tube 3 it will be free and hæmolysis will take place.

damp soil; and that it is not killed by ordinary cold. Therefore, all discharge and soiled linen from cholera cases should be immediately disinfected or destroyed, and every precaution must be taken during convalescence, as well as during the acute stage, to prevent contamination of wells, public water supply, drinking and table vessels, and food. The domestic fly and other vermin as vectors of the germ must not be overlooked.

CHAPTER XXIX

DYSENTERY

Definition.—A term applied to several specifically distinct diseases of which the principal pathological feature is inflammation of the mucous membrane of the colon, and of which the leading symptoms are pain in the abdomen, tenesmus, and the passage of frequent small stools containing slime, or slime and blood.

Geographical distribution.—From time to time forms of dysentery have extended as epidemics of great severity over vast tracts of country. These great epidemics, or, rather, such of them as have been recorded, have been confined principally to temperate latitudes. There can be little doubt that similar visitations have occurred and do occur in tropical countries. At the present day dysenteric disease is rare in Britain. Small circumscribed epidemics break out occasionally among the general population, and in certain public institutions, particularly lunatic asylums, endemic dysentery is common; but, in comparison to what was the case in pre-sanitary days, and with what obtains in tropical countries at present, our indigenous dysentery is altogether insignificant. The same remark applies to the continent of Europe. But when, in Europe or elsewhere, war breaks out, or when there is widespread scarcity of food, dysentery is almost sure to appear. In most places in the tropics dysentery of one form or another is always to be found; in some places and seasons more than in others. On the whole, it may be advanced that wherever the general hygienic conditions are bad, wherever the soil is much fouled by excreta, and especially where the water supply is polluted, wherever many people are crowded together in one building or camp, where the food is coarse, mono-

tonous or unsound, there, especially in tropical and sub-tropical climates, dysentery is or becomes endemic, and may become epidemic.

Amongst tropical diseases the group of morbid conditions included by the general term "dysentery" ranks in importance next to malaria. Unfortunately, our knowledge is not in proportion to the importance of the subject. Until recent years the word "dysentery" was supposed to indicate a single well-defined disease; writers described its etiology, symptoms, pathology, morbid anatomy, and treatment with precision. Lately we have begun to get beyond this stage of confident ignorance. We may know something about the symptoms and morbid anatomy of dysenteric disease, and we are beginning to get some insight into the germ causes of the leading types, but we are obliged to confess that even in these respects our knowledge is not even approximately complete. Anything approaching a scientific description of dysentery is as yet impossible. I am obliged, therefore, in describing the clinical features of dysentery to adopt an arbitrary and unscientific classification; and to deal with effects before discussing possible causes, symptoms before etiology.

Symptoms.—In ordinary cases the leading symptoms of dysentery are those of inflammation of the great intestine—namely, griping, tenesmus, and the passage of frequent, loose, scanty, muco-sanguineous stools. The illness commences in various ways—insidiously or suddenly; with high fever, with moderate fever, or without any material rise of temperature. Or the symptoms of colitis may be grafted on to some general affection, such as scurvy or malaria, or on to some chronic disease of the alimentary canal, such as sprue. They may assume acute characters; or from the outset the symptoms may be subdued and of little urgency. As a rule, the symptoms are proportioned to the extent of the disease, but they are not necessarily so. In certain cases they may be extremely urgent and in apparent disproportion to the area of bowel affected; or they may be, in comparison to the extent and the degree of the anatomical

lesion, disproportionately trifling; or they may be altogether absent, even when the colon is extensively diseased. There is, therefore, endless variety in their character, urgency, and significance. As a general rule, the nearer to the rectum the lesions, the more urgent the tenesmus; the nearer to the cæcum, the more urgent the griping. These two symptoms, together with the presence of points of localized tenderness, form, in many cases, a fair guide to the location and extent of the lesions.

Clinically, the dysenteries are conveniently arranged according to what may be presumed to be the gross characters of the attendant intestinal lesion.

Catarrhal dysentery.—A common history to receive is that for some days the patient had suffered from what was supposed to be an attack of diarrhœa. The stools, at first copious, bilious, and watery—perhaps to the number of four or five in the twenty-four hours—had latterly, and by degrees, become less copious and more frequent, less fæculent and more mucoid, their passage being attended by a certain and increasing amount of straining and griping. On looking at what was passed, the patient had discovered that now there was very little in the pot except mucus tinged, or streaked, or dotted with blood; a tablespoonful, or thereabouts, being passed at a time. By degrees the dysenteric element entirely supplanted the diarrhœa; so that when seen by the physician the desire to go to stool had become almost incessant, the effort to pass something being accompanied by perhaps agonizing griping and tenesmus. The patient has hardly left the stool before he has a call to return to it, and he may be groaning and sweating with pain and effort. The suffering is sometimes very great; nevertheless, with all this suffering there is often very little fever, the thermometer showing a rise of only one or two degrees.

In another type of case the incidence of the dysenteric condition is much more abrupt. Within a few hours of its commencement the disease may be in full swing. The stools, at first fæculent, soon come to consist of little save a yellowish, greenish, or dirty-

brown mucus—blood-tinged or streaked and dotted with little hæmorrhages. Very soon the desire to stool becomes increased, the griping and tenesmus being accompanied, perhaps, with most distressing dysuria. The patient is glued, as it were, to the commode. Fever, which at the outset may have been smart and preceded by rigor, subsides, so that when the patient is seen it may be absent or inconsiderable. The tongue soon becomes white or yellow-coated; there may also be thirst; very generally anorexia is complete.

In either case, after perhaps four, five, or six days, the urgency of the symptoms may gradually diminish and the acute stage taper off into a subacute or chronic condition; or it may terminate more quickly in perfect recovery.

Ulcerative dysentery.—Should, on the contrary, the disease advance, the urgency of the symptoms shows hardly any abatement; the stools become very offensive, and now contain, besides blood, large or small shreddy, ash-coloured, stinking sloughs. This may go on, better or worse, for days or weeks. Recovery from this condition is, necessarily, a slow process, seeing, as the presence of sloughs in the stools indicates, that there is deep ulceration which must take some time to cicatrize. Such a condition tends to drift into that most dangerous and most distressing complaint, chronic dysentery, relapsing and improving during many months or even years, and causing, if severe and prolonged, great wasting, pain, and misery.

Fulminating dysentery.—The attack generally begins suddenly, often in the middle of the night, with chills or smart rigor, vomiting, headache, and a rapid rise in temperature to 102° or even 104° F. Coincidently with the rigor, or very soon afterwards, but occasionally not for a day or two, purging begins, the stools quickly assuming dysenteric characters. In from two or three days to a week or thereabouts, fever persisting to the end, or collapse setting in with a subnormal temperature, the patient dies. So virulent is the blood-poisoning in some instances that death may take place before dysenteric stools are emitted, and it

is only the presence of an epidemic of dysentery at the time, or the post-mortem revelations, that make diagnosis possible. The mortality in such cases is very high. Occasionally the acute phase subsides, the patient slowly recovering after passing through the ulcerative phase of the disease.

Relapsing dysentery.—In a proportion of dysenteries, although the activity of the initial attack may subside somewhat, symptoms do not completely disappear. The stools may recover their fæculent character and even show some formation, but they continue to be passed too frequently, are often preceded by griping, and contain a variable amount of slime and muco-pus, with or without blood. Without obvious cause, or as a sequel of some dietetic or other indiscretion, these dysenteric signs become aggravated, and there is once more a recurrence of active symptoms. Spontaneously, or through treatment, matters quiet down again, presently, however, to be followed by another relapse; and so on, until after weeks or months of suffering the patient dies of exhaustion or slowly recovers. This is the type of dysentery, as will be explained presently, that is generally associated with, and in all probability is caused by, a specific amœba, and designated "amœbic dysentery."

Recurring dysentery.—The patient has an attack of dysentery from which recovery appears to be complete. Months, or even years subsequently, without recognizable fresh exposure to infection, and during prolonged residence perhaps in a non-endemic district or country, the disease recurs, to subside and recur at intervals for several years. I have several times seen such cases. They can only be explained by assuming a remarkable capacity for prolonged latency on the part of the special dysenteric germ, amœba or bacterium, concerned.

Chronic dysentery.—In a large proportion of cases of acute dysentery the bowel does not become absolutely healthy for a considerable time after abatement of the more urgent symptoms. On the slightest dietetic imprudence, after chill or fatigue,

or even slight indulgence in alcohol, the old symptoms reappear. In such cases sudden attacks of diarrhœa are common. Some patients for months, or even years, never pass a perfectly healthy stool, the unformed motion always containing slime or mucopus, and at times blood. Often there is a tendency to scybalous stools, or to constipation alternating with diarrhœa. If such symptoms are at all severe, or persist for a long time, the digestion may deteriorate and the patient become thin and cachectic, his complaint assuming many of the characters of sprue. On the other hand, general nutrition may not suffer, although the patient may continue for years to pass two or three unhealthy stools daily. In mildness and severity the more chronic types of dysentery are as manifold and varied as are the earlier and more acute phases of the disease. They, too, are usually of amœbic nature.

Anomalous types of dysentery have been described from time to time. Thus in a special report on an outbreak among Polynesian immigrants to Fiji which occurred on board ship in 1890, Daniels describes a disease of high fatality (15 deaths in 31 cases), manifestly infectious, running a rapid course—death taking place in from two to ten days. In 6 cases there was extensive superficial ulceration of the mouth, and in 2 cases diphtheritic inflammation of the prepuce. Post-mortem examinations were made in four cases. In all, the whole of the colon and at least half of the small intestine were found acutely inflamed, superficially ulcerated, or covered with a firm, dry, green or grey layer adherent to or continuous with the subjacent intestinal wall. In a special report (1898), Dr. Corney, of Fiji, remarks that at least six similar epidemics had occurred in Melanesian immigrant vessels in twelve years. The high degree of infectiveness, the diphtheritic lesions in intestine and prepuce, and the great mortality clearly indicate a special form of enterocolitis, due probably, according to later researches, to a very virulent form of dysentery bacillus. Such cases do not occur under the better hygienic conditions

obtaining in the Melanesian immigrant vessels at the present day.

Gangrenous dysentery. — What is known as gangrenous dysentery is, symptomatically, merely an aggravated form of acute ulcerative dysentery, or a sequel of the fulminating type. Instead of being mucoid, the stools come to consist of a sort of thin, dirty fluid, like the washings of flesh. On standing they deposit a grumous, coffee-grounds-looking material, and they stink abominably. Now and again sloughs of every shape, size, and colour, from ash-grey to black, are expelled. Sometimes tube-like pieces, evidently rings of mucous membrane which have been cast off *en masse*, are discharged. In such cases the patient rapidly passes into a state of collapse. He sweats profusely; the features, the extremities, and even the whole body, are cold and pinched as in the algide stage of cholera; he may vomit from time to time, and the belly may become distressingly tympanitic. In this condition there is usually a persistent and worrying hiccough. Low muttering delirium sets in; the pulse becomes small and running, and the patient rapidly sinks. Recovery is extremely improbable. Nevertheless, such cases have recovered, and must not necessarily be despaired of.

Hæmorrhage.—Whenever in dysentery sloughs separate, smart hæmorrhage is always possible. Sudden collapse may occur from this cause, even in otherwise mild cases. As in typhoid, the occurrence of hæmorrhage is more or less of the nature of an accident, depending, as it does, on the position of the sloughing sore in relation to an artery; of course, the more extensive and the deeper the sloughing, the greater the liability to hæmorrhage.

Perforation.—Another grave, though fortunately rare, accident in the course of dysentery is the occurrence of perforation. Should this unhappily take place, and if the patient survive the shock of an extensive extravasation into the peritoneum, symptoms of peritonitis will supervene and rapidly prove fatal.

Intussusception.—Intussusception is also an occasional occurrence, especially in children. It is not always readily recognized. A sudden increase of pain, increased straining, entire absence of fæcal matter from the stools, vomiting, and perhaps the presence of a tumour in the rectum, might lead one to suspect and examine for this accident.

Tenderness; thickening.—The abdomen is tender in most cases of acute dysentery. If the disease be of some standing a certain amount of thickening may be felt along the track of the colon, particularly over the sigmoid flexure.

Appendicitis.—Symptoms suggesting inflammation of the appendix due to ulceration of that organ are often met with in amœbic dysentery, and probably account in part for the number of appendicectomies performed in tropical countries.

Hepatitis.—In acute cases the liver is usually distinctly enlarged, and may be tender. It sometimes happens that attacks of hepatitis seem to alternate with attacks of dysentery; or, rather, that hepatitis increasing, dysenteric symptoms decrease, and vice versa. These are always very anxious cases, and too often eventuate in the formation of an abscess or multiple abscesses in the liver; in the latter event they almost necessarily prove fatal.

Sequelæ.—Apart from chronic intestinal troubles, dysentery may be followed, as is the case in so many other infections, by peripheral neuritis. A condition resembling gonorrhœal rheumatism has frequently been noted as a sequel, and at least one epidemic has been recorded in which a large proportion of the cases became affected in this way. Abscess of the liver is the most important of the sequelæ of dysentery; it will be treated of separately, and need not be further alluded to here.

Mortality.—Although every now and again cases are met with which prove directly fatal, from an overwhelming initial dose of virus, or from the shock of an extensive and intense lesion, or from rapid exhaustion from hæmorrhage, or from perforation; and though some epidemics exhibit a malignancy which,

fortunately, is not very common, the direct and immediate mortality from this disease is, under modern methods of treatment, not very high. In India, the case mortality in dysentery among Europeans ranges from 3 to 22 per cent.; among natives, about 37 per cent. In Egypt, Griesinger stated it as 36 to 40 per cent. In Japan, Scheube places it at 7 per cent. These figures are of little value, as so much depends on the place and the type of the epidemic, and the range of cases covered by the statistics. There was a time when, under a spoliative treatment by bleeding and calomel, dysentery proved a very fatal disease indeed. Even now, in the presence of scorbutus, famine, the stress of war, and similar conditions, whenever dysentery becomes epidemic in a community it is apt to claim a large number of victims.

Sequelæ more dangerous than the disease.—As a rule, under modern treatment, it is the sequelæ of the disease that we have to fear rather than the disease itself. The chronic ulceration, the scarring, thickening and contractions of the gut are irremediable conditions which too often, after months or years of suffering, lead to intestinal obstruction or, very frequently, to atrophy of the glandular and absorbent system of the entire alimentary tract, general wasting and fatal asthenia. Such patients hardly ever pass a healthy motion; they are troubled with chronic indigestion; at times they pass their food unaltered; they have recurring attacks of diarrhœa; they are flatulent; their tongues are red, often ulcerated and tender; they develop the condition known as "sprue," and sooner or later almost invariably succumb.

Morbid anatomy. *Catarrhal dysentery.*—In those cases that subside in a few days, whether spontaneously or in consequence of treatment, it is reasonable to suppose that the pathological condition consists only, or mainly, in congestion or in catarrhal inflammation; that here and there, or throughout its extent, the mucosa and perhaps submucosa of the colon are slightly swollen and congested; and that the surface of the former is softened, perhaps eroded, and covered with a blood-streaked glairy mucus

of the same character as that which appears in the stools.

Ulcerative and gangrenous dysentery.—Cases of catarrhal dysentery rarely die; the exact conditions of the mucous membrane, therefore, in these cases can only be conjectured. It is otherwise in the severer forms of the disease. When such cases come to the post-mortem table the mucous membrane of the large intestine and, very frequently, a foot or two of the lower end of the ileum are found to be thickened, congested, inflamed, speckled perhaps with ecchymoses, œdematous, and more or less riddled with ulcers or patches of gangrene of various sizes, shapes, and depths. As a rule, the brunt of the disease falls on the sigmoid flexure and descending colon; not infrequently, the lesions are equally if not more advanced in the cæcum and ascending colon, and may involve a foot or two of the lower end of the ileum. On the whole, the transverse colon, though often seriously implicated, is so to a less extent than one or other of the parts mentioned, or than the hepatic and splenic flexures.

The dysenteric ulcer varies in size from a punched-out-looking sore the size of a pea, or even less, to a patch several inches in diameter. As a rule, in the earlier days of the acute stage the ulcers tend to follow the folds of the mucous membrane, the free borders of which are the parts most liable to implication. The edges of the sores are ragged and undermined, the floor is sloughy and grey. There may be considerable thickening of the edges and base of the ulcer, and there may be peritoneal adhesions. The appearance of the ulcer may suggest that it extends by a process of burrowing in the submucosa, the superjacent membrane sloughing or disintegrating in consequence of the destruction of its subjacent nutrient vessels. This burrowing may extend for a considerable distance beyond the apparent margin of ulceration; so much so that long, suppurating, fistulous tunnels may connect one ulcer with another. In this way large patches of mucous membrane come to be undermined, and subsequently to slough away. Sores so formed are

necessarily ragged and irregular in outline, and may even surround pieces of comparatively healthy mucous membrane. The floor of the active dysenteric ulcer may be, and generally is, formed of a sloughy material lying on the muscular coat; but the sore may penetrate deeper than this, and include the muscular coat itself, and even the serous membrane. The largest ulcers are generally found in the sigmoid flexure and descending colon; they are also frequently, though more rarely, found in the cæcum, the magnitude of the lesions diminishing as we trace the bowel upwards or downwards, as the case may be.

Along with the ulceration there is intense congestion of the non-ulcerated parts of the mucous membrane. In places there may be œdema of the submucosa; there may be small abscesses which elevate the mucous membrane; and there may also be distension of the solitary follicles by a mucoid or purulent material. In some instances a large portion of the mucous membrane may be seen to have died *en masse* and become gangrenous. In such, extensive sloughs may be thrown off as a sort of tube, apt to be mistaken during the lifetime of the patient for a diphtheritic cast of the bowel.

Fulminating dysentery.—Strong and Musgrave thus describe the lesions in this type of dysentery as it occurs in the Philippine Islands:—"In the most acute cases (death after three or four days' illness) the mucous membrane of the large intestine presents in general a reddened, swollen, puffy appearance. There is a superficial necrotic mucous layer which generally extends over the mucosa throughout the large bowel, and sometimes for a distance of 10 or 12 cm. into the ileum. This necrotic layer consists of mucus, red blood-corpuscles, leucocytes, epithelial cells, with many large swollen granular cells, and bacteria; no amœbæ are found. If one brushes the mucous layer lightly aside with the finger the bright-red injected appearance of the intestinal wall becomes more plainly visible. Dotted here and there throughout are small, diffuse, bright-red hæmorrhages with irregular margins, measuring

from 2 to 4 mm. in diameter, or even more. The solitary follicles are generally swollen and raised, and of a bright-red colour. Here and there, scattered among them, bright-red, sharply circumscribed, small purpuric spots may appear. Occasionally the background of the intestine may be described as though covered with a bright-red eruption, but with darker red hæmorrhagic points scattered over this background. In the acute cases no definite ulceration takes place, but only a superficial coagulation necrosis of the mucosa." The lower end of the ileum may be similarly affected. Mott's description of the lesions in the fulminating form of asylum dysentery, as it occurs in England, agrees practically with the foregoing. He adds: "Acute fatal cases of a little longer duration show the same swelling, but now frequently the mucous lining, although swollen, presents a pale-grey or dirty whitish-grey appearance; the surface is sometimes finely or coarsely granular. This is owing to stasis in the vessels of the submucosa and necrosis of the epithelium, and the formation of a *false membrane*, consisting for the most part of leucocytes and disintegrating epithelial cells."

The primary lesion.—Such, briefly, are descriptions of the principal lesions found in the acute stage of fatal dysenteries. There is general agreement among pathologists about these; but there is very great discrepancy of opinion as to the exact nature of the primary and essential lesions. Some maintain that the starting-point of the disease is in the solitary follicles, which, becoming distended by a specific exudation, afterwards slough, and form the starting-point for a spreading ulcer. Other pathologists regard the primary lesion as being altogether independent of the glandular structures of the mucous membrane. They hold that, in consequence of the irritation produced by the specific cause of dysentery, an exudation is thrown out on to and into the mucous membrane itself: a slough is formed of this, the implicated piece of tissue being subsequently got rid of, very much in the same way as the slough forming the core of an ordinary boil.

Another primary lesion described is the small abscess, alluded to as elevating the mucous membrane and projecting into the lumen of the gut. These minute, pimple-like abscesses consist of a collection of gummy pus. After a time a tiny opening forms at the apex of the little swellings, through which the contents may be expressed: it is this opening which, it is alleged, forms, on enlarging, the specific ulcer of dysentery.

Assuming that there are several specific causes for dysentery, it is to be expected that the corresponding primary lesions should differ; that whilst one causes a suppurating or a gangrenous lesion, another may produce a croupous or a diphtheritic; that whilst one species of dysenteric germ attacks the mucosa, another species may select the submucosa; one may attack the glandular structures, another the connective tissue, another the epithelial layer. Whatever the primary lesion may be, eventually the weakened tissues are attacked by the ordinary bacteria of suppuration; so that finally, if the cases survive long enough, they all present a certain uniformity as regards the ultimate ulceration, thickenings, and other inflammatory lesions disclosed post-mortem.

Healing process.—The dysenteric ulcer heals partly by contraction, partly by the formation of a very thin scar tissue—scar tissue which, besides contracting, is apt to become pigmented. Lost glandular structures are never reproduced. Owing to the constant peristaltic movement of the gut, and the passage of fæces over the face of the healing ulcer, cicatrization, as might be supposed, is a slow process, and one prone to interruption by recurring attacks of inflammation of a more or less specific nature.

Lesions in chronic dysentery.—In chronic dysentery the ulcers are usually smaller and less numerous than in the acute disease. They are also less ragged in outline, tending to become circular in shape and to acquire thickened rather than undermined edges. Cicatricial bands and contractions may narrow the lumen of the gut, the functions of which are still further hampered by thickenings, or by adhesions which unite and bind it to neighbouring organs. Dilatation above

the seat of cicatricial stricture is liable to ensue. In chronic dysentery large patches of the bowel, and even the ulcers themselves, may be pale and anæmic, whilst at the same time other patches of the gut are congested. Some parts may be thickened and contracted; others, again, may be thinned and dilated, the glandular structures being atrophied. Lesions of the appendix are often found in amœbic dysentery. Symptoms of appendicitis occurring in countries where appendicitis and consequently appendicectomy are common should incite the tropical practitioner to examine the stools for amœbæ and to apply the appropriate treatment.

Polypoid growth.—Some time ago I attended a case of chronic relapsing dysentery in which the mucous membrane, at all events of the rectum and descending colon, was covered with enormous numbers of polypoid growths of considerable magnitude, some of them at their free ends being as large as the tip of the little finger. The growths had pedicles 1–2 in. in length. During life these polypoid bodies appeared in the stools, often in great number, looking like so many mucilaginous seeds. Similar cases are occasionally met with.

Liver; mesenteric glands.—In by far the majority of cases of acute dysentery the liver is hyperæmic and swollen. In about one-fifth of the cases of Indian dysentery which come to the post-mortem table the liver is the seat of single or multiple abscesses. In chronic dysentery this organ may be atrophied; very generally it is the subject of fatty degeneration.

In acute cases the mesenteric glands are enlarged, soft and congested, or even hæmorrhagic; in chronic cases they are enlarged, hard, and pale. None of the other viscera is characteristically affected. Abscess is sometimes discovered about the rectum. If perforation has occurred, there may be signs of commencing peritonitis.

Etiology.—From a study of the natural history of the various types of the disease we are forced to the conclusion that at least three factors are concerned in the production of the clinical condition called dysentery, namely (1) influences that weaken the natural resistance of the bowels, such as the depressing or

congesting effects of chill, bad food, purgatives, intemperance, intestinal nematodes and trematodes. These prepare the ground for the action of (2) specific germs which have their action supplemented subsequently by (3) the ordinary bacteria of suppuration and ulceration. It must be with the mucous membrane of the bowels in these respects as it is with the skin of the surface of the body. For example, a traumatic erythema leads to a specific eczema which, in turn, may end in an ulcer. So with the bowel: a debauch, a chill, or bad food may lead to an intestinal catarrh. A specific germ, which in healthy conditions would not have proved pathogenic, coming on the scene produces a lesion of the mucosa, in which the ubiquitous pus germs find their opportunity.

Three types of dysentery, correlated to three different kinds of parasites, are now fairly well made out. These are not mutually exclusive; one type may be superposed on and complicate another. That there are other dysenteries, similarly correlated to parasites as yet unrecognized, is not to be doubted. The principal recognized types and their respective parasites are as follows:—

1. BACTERIAL—
   Bacillary dysentery:
   Bacillus dysenteriæ (Shiga and Flexner).
   Bacillus pyocyaneus.

2. PROTOZOAL—
   Amœbic dysentery:
   Entamœba tetragena (*histolytica*).
   Balantidium dysentery:
   Balantidium coli.
   Kala-azar dysentery:
   Leishman-Donovan body.
   Malarial dysentery:
   Malaria parasites.

3. VERMINOUS—
   Schistosomum japonicum.
   Schistosomum hæmatobium.
   Schistosomum mansoni.
   Œsophagostomum apiostomum.

In this place I shall discuss briefly (1) bacillary dysentery; (2) amœbic dysentery; (3) balantidium dysentery. Reference to the other forms will be found under their respective parasites.

Bacillary or Epidemic Dysentery

The characteristics of this type of dysentery, at all events of that type of bacillary dysentery which has received of late so much attention, are acuteness of onset, often a well-marked initial fever, little tendency to relapse after the initial attack, the presence of *Bacillus dysenteriæ* in the stools, an initial diphtheroid necrosis of the mucosa of the large intestine, non-liability to abscess of the liver, occurrence in epidemic form and in all latitudes, and in the lunatic asylums of this and other countries.

Celli and Fiocca believed that dysentery is caused by *Bacterium coli commune*, which, they asserted, is always present in the stools in this disease. Generally non-pathogenic, this bacterium, they stated, acquires in certain circumstances virulent properties. They said that in the bowel it is often associated with a bacillus like that of typhoid, as well as with streptococci; and they asserted that introduced by the mouth, or injected by the rectum, any or all of these, particularly when in combination and in certain not understood circumstances, either singly or in combination, excite dysentery. They supposed that what they call *Bacterium coli dysenteriæ* is but a variety of *Bacterium coli commune*, a variety brought about in some way by the presence of the other bacteria mentioned; that in consequence of the presence of these other bacteria *Bacterium coli commune* acquires the power of secreting a specific toxin, which power it retains on being transferred from one human being to another. The toxin can be precipitated by alcohol from cultures, and has the property of giving rise to dysentery when administered by the mouth, the anus, or hypodermically.

Shiga was the first to call marked attention to what is now known as *Bacillus dysenteriæ*, which Celli regards as identical with the organism just alluded

to. Flexner, Strong, Musgrave and others regard it as the cause of what they termed *epidemic dysentery*, in contradistinction to *sporadic* or *endemic dysentery*, which they regard as belonging to the pathogenic sphere of the pathogenic amœba. It is a rod-shaped bacillus with rounded ends, varying in size somewhat according to the culture medium, from 1 to 3 μ in length by 0·4 to 0·5 μ in breadth. It closely resembles in its properties *Bacillus typhosus*, but differs in being non-motile and exhibiting active Brownian movement, and in the circumstance that some types of *B. dysenteriæ* display a more uniform generation of indol than does *B. typhosus*. After a brief preliminary acid production in milk, it gives rise to a gradually increasing alkalinization; it does not agglutinate in serum from typhoid cases, but reacts in serum from dysenteric cases to which *B. typhosus* does not respond (Flexner). Opinions differed at first as to the presence of flagella; it is now generally conceded that they are absent. It occurs in greatest abundance in dysenteric lesions and especially in the solitary lymphatic follicles of the large intestine, and in the mucus in the stools during the most acute stage of "epidemic" dysentery. It is pathogenic to many animals, but it does not produce in them, or only exceptionally, dysenteric lesions, although the toxins of the bacillus, pounded and killed cultures, when injected intravenously into rabbits and other animals, produce necrosis of the large intestine into which they are excreted by some selective action. One c.c. of the filtrate of freshly isolated dysentery cultures injected intraperitoneally is fatal to a rabbit. In two experiments on man, one intentional, the other accidental, ingestion of the pure cultures was followed, within a short time, by well-marked symptoms of dysentery. The bacillus agglutinates with the blood serum of "epidemic" dysentery in dilutions of 1 in 10 to 200.* Further-

* The agglutination reaction of the dysentery bacillus cannot be regarded as specific, in the same sense as Widal's reaction in typhoid. The lack of motility of the bacillus, its tendency to clump in broth cultures and also to agglutinate in low dilutions with normal sera, partially account for this. Two types of agglutination occur—(1) in chains, the bacilli lying end to end; (2) in clumps.

more, Shiga claims by immunizing animals to have produced a serum which has reduced the mortality in "epidemic" dysentery in Japan from about 35 per cent. to 9 per cent.

The cultural characters of *B. dysenteriæ* are subject to great variation. As a consequence considerable confusion has arisen; but it is now generally conceded that, though indicating different strains of bacilli, these differences are not specific. The table which will be found on p. 499 indicates the leading characteristics of the various strains and a comparison with other pathogenic intestinal bacilli.

Many strains of *B. dysenteriæ* have been described, and though all resemble each other in their gross cultural characters on solid media, etc., yet they differ considerably from each other in their chemical reactions with solutions of various sugars and in their production of indol. Thus Ohno has described over fifteen varieties, but more recent work indicates that there are probably nothing like this number, and that many of the sugar reactions not only vary according to the length of time of subculture, but even from day to day for given strains of the bacillus. On only one point is there universal agreement, and that is in the property of producing acid from mannite possessed by bacilli of the acid or Flexner group, and the lack of acid production in this sugar by the non-acid or Shiga group. Shiga now recognizes five types which he uses for the production of polyvalent antiserum in Japan. These are:

(1) Fermenting dextrose alone (Shiga-Kruse).
(2) The true Flexner bacillus, fermenting dextrose and mannite and saccharose.
(3) The "Y" bacillus, fermenting dextrose and mannite.
(4) Fermenting dextrose, maltose and saccharose.
(5) Fermenting dextrose and maltose, but giving only a feebly acid reaction with mannite.

There is also great variation in the toxicity of various strains of bacilli, especially after long subculture on artificial media. The serum of an animal injected with one strain will agglutinate bacilli of another in high dilutions. Even the serological tests of patients suffering from dysentery caused by one type of bacillus give uncertain results. Penfold and others have shown that cultural reactions which are constant for one type of bacillus can be made to vary by growing the same bacillus under different conditions, and even passage through the intestinal tract of a fly may exert a temporary influence on their power of fermentation (Bahr). The three main types of bacilli now recognized are the Shiga-Kruse, the Flexner, and the bacillus of Hiss and Russel. (*See* Table on p. 499.)

These bacilli are encountered in sporadic cases or in different epidemics without an apparant preponderance of any one type. Thus two or more types may be present in the one case. Nor do they bear any relation to the clinical type of case (mild or severe) with which they are associated.

In the *Journal of Experimental Pathology* (1898) there appears an account of a limited but very fatal epidemic in the United States in which *Bacillus pyocyaneus* was found. Calmette and Maggiora report that they also have encountered this bacterium in dysentery, as well as in infantile diarrhœa.

The case mortality from bacillary dysentery varies greatly in different parts of the world, depending to a great extent on the age and social status of those attacked. In Japan it is about 24 per cent.; in French epidemics it has been as high as 50 per cent.; in Fiji it is about 13 per cent. at the present day, though formerly a much more fatal form existed. It is especially fatal to children, in whom it is commonly found, and in whom the toxic effects are most marked; death being due to heart failure, probably consequent on toxic absorption.

Pathology of bacillary dysentery.—The large intestine is the seat of the affection; the last few feet of the ileum as well may be attacked in some cases. In early cases the gut wall is thickened and infiltrated, the mucous membrane œdematous and of a cherry-red colour showing small yellow superficial ulcers along the exposed borders and folds. In severe cases, or cases in which the disease has lasted for some time, the mucous membrane may be entirely gangrenous, of a bright-green colour, and forming what appears to be a false membrane on the surface of the bowel. This change extends down to the anus, though the cæcum and the sigmoid flexure are the areas most severely attacked. The puckered or stippled appearance of this green layer is very characteristic. At a further stage large pieces of mucous membrane slough away, leaving ragged irregular ulcers and exposing the muscular coat. The process appears to start from the solitary lymphoid

TABLE SHOWING THE MORPHOLOGICAL AND CULTURAL CHARACTERISTICS OF BACILLUS DYSENTERIÆ AND THE ALLIED GROUP OF MICRO-ORGANISMS AFTER TWENTY-FOUR HOURS' INCUBATION AT 37° C.

ORGANISM	CHARACTER	MOTILITY	FLAGELLA	GLUCOSE PEPTONE WATER	MALTOSE PEPTONE WATER	LACTOSE PEPTONE WATER	SACCHAROSE PEPTONE WATER	MANNITE PEPTONE WATER	DEXTRIN PEPTONE WATER	LITMUS MILK	POTATO	GELATIN STAB	INDOL
BACILLUS TYPHOSUS	Oval rods with rounded ends 2 μ × 0·6 μ	+	8—12	A	A	0	0	A	A	A slight	Scanty moist yellowish growth	Slight white growth in 48 hours. No gas	None.
BACILLUS COLI *	Oval rods 2·4 μ × 0·4-0·6 μ	∓	3—4	AG	AG	AG	AG∓	AG	AG	A/Clot	Thick moist brownish growth	Slight white growth Gas bubbles	+
BACILLUS ENTERITIDIS (Gärtner)	Same as typhoid	+	Peritrichous flagella	AG	AG	0	0	AG	AG	A/Alk.	Same as typhoid	Same as typhoid	∓
BACILLUS PARATYPHOSUS (A. Brion-Keyser and B. Schottmüller)	Same as typhoid	+	8—12	AG	AG	0	0	AG	AG	A/Alk.	"	"	None.
SHIGA'S DYSENTERY BACILLUS	Fine rods with rounded ends 1 μ in length × 0·5 μ	None	None	A	0	0	0	0	0	A/Alk.	Thin grey growth	Thin slimy growth	∓
FLEXNER'S DYSENTERY BACILLUS	"	None	None	A	0	0	A	A	A	A/Alk.	"	"	∓
HISS and RUSSEL'S PARADYSENTERY "Y BACILLUS" †	"	None	None	A	A∓	0	0	A	0	A/Alk.	"	"	∓

* Produces fluorescence in neutral red glucose peptone water. † In asylum dysentery, especially in Germany.

A = Acid. AG = Acid and gas. 0 = No change. A/Alk. = Acid first, alkaline after further incubation.

∓ = Variable: sometimes positive, sometimes negative.

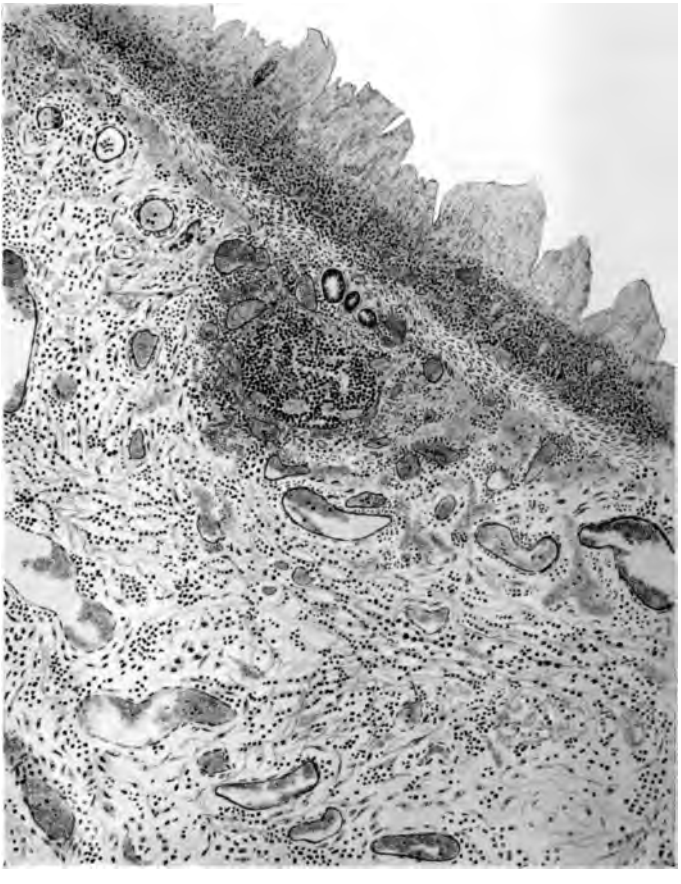
follicles of the large intestine. The rest of the small intestine may be slightly injected, or may be normal. The mesenteric glands may be enlarged; other abdominal organs are normal. The intestinal contents consist usually of tenacious, slimy mucus intermingled with thick green fæcal matter; fæcal matter may be absent and merely blood-stained mucus resembling frog's spawn, or, on the other hand, solid fæces, may be found. Intestinal adhesions may occur, but perforation is extremely rare.

The microscopic pathology varies with the severity of the lesions. In the gangrenous form the epithelial cells of the mucous layer can no longer be distinguished, the whole of the mucous membrane undergoing coagulation necrosis with destruction of the glandular elements. The muscularis mucosæ may be intact, or in places destroyed. The outstanding feature is the infiltration of the submucosa (Plate VIII.) and destruction of the nutrient blood-vessels. (These appearances are extremely similar to those produced in the large intestine by intravenous injection of dysenteric toxins into rabbits.) In subacute cases portions of the crypts can still be distinguished, but the cells stain badly and are vacuolated, and the submucosa is invaded by large wandering plasma cells, liable in sections to be mistaken for amœbæ. Dysentery and other bacilli can be seen crowding the mucous layer and in the lymphoid follicles, but bacilli are not found in the submucous layer save where there is a break in continuity of the muscularis mucosæ. The muscular coat is normal.

By employing the appropriate technique (*see* p. 519) the dysentery bacillus can be isolated from the necrotic mucous membrane and also from the mesenteric glands, occasionally from the gall-bladder, but never from the blood.

Amœbic Dysentery

As distinguished from other forms the characteristics of this type of dysentery are, generally, insidious onset, marked tendency to chronicity, relapses alter-



Microscopical section of the large intestine in bacillary dysentery, showing necrosis of the mucosa, cellular infiltration and hæmorrhages into the submucosa. (*After Bahr.*)

PLATE VIII.

nating with periods of comparative quiescence, great liability to abscess of the liver, confinement to warm climates or the warm season of temperate climates, local endemicity, the presence of *Entamœba tetragena* * in the stools and implicated tissues. The intestinal lesion consists primarily of small amœbic abscess formations in the submucosa and the subsequent undermining and necrosis of the superjacent mucosa.

According to Rogers this is by much the most common variety of dysentery in India, being at least twice as common as the bacillary. Cases occasionally originate in Great Britain.

As a practical point it may be mentioned that amœbic dysentery may concur with bacillary, or with balantidium, or with verminous dysentery. This circumstance must not be overlooked, either in practice or in pathological studies.

The amœba.—The discovery of the presence of amœbæ in the stools of dysenterics, originally pointed out by Lösch, naturally created much interest. Although within the last few years a large literature has grown up around the subject, and although some definite conclusions, both as regards the bionomics of the amœba and its relationship to the disease, have been arrived at, some confusion and uncertainty still remain. Originally regarded by pathologists as a single and definite organism, and called *Amœba coli*, it now appears that there are probably several distinct species of amœbæ to be found in the intestinal canal of man, some of which are pathogenic, others possibly harmless; some true parasites, others ordinary saprophytic amœbæ. Schaudinn maintained that there are two well-defined true parasitic species; these he named respectively *Entamœba coli* and *Entamœba histolytica*. The former he regarded as non-pathogenic, the latter as the specific germ of amœbic dysentery. Although more recent proto-

* Although, according to the rules of zoological nomenclature, the specific title of *histolytica* still holds, I have adopted that of *tetragena* as being more descriptive of its life cycle as at present understood, and as less calculated to cause confusion.

zoologists have upset some of Schaudinn's views on the bionomics of the dysentery amœba, and have renamed it *Amœba tetragena*, pathologists have con-

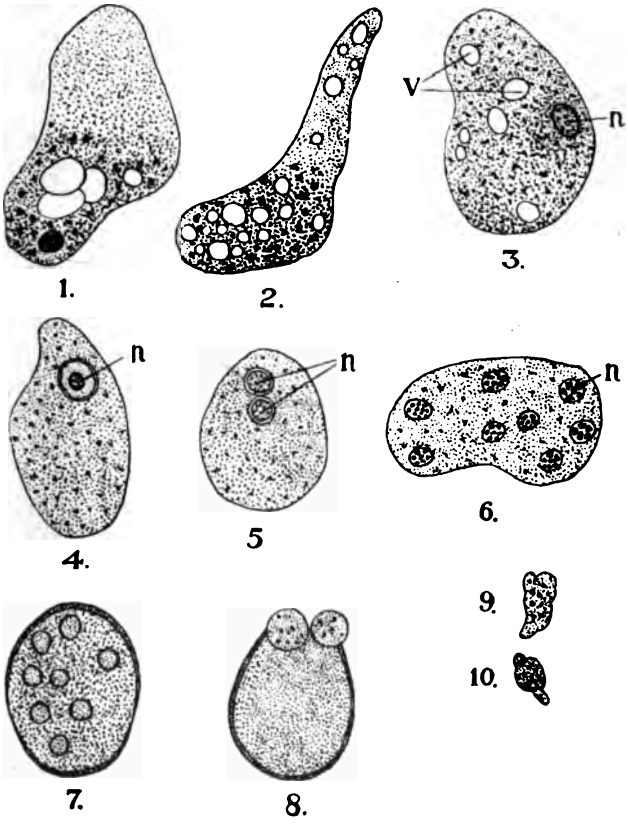


Fig. 78.—Entamœba coli. (*After Casagrandi and Barbagallo, Allbutt and Rolleston's "System of Medicine."*)

1, 2, Living amœbæ showing changes of form and vacuolation of the endoplasm; 3, 4, 5, amœbæ showing different conditions of the nucleus (n); 6, amœba with eight nuclei preparing for multiple fission; 7, encysted amœba containing eight nuclei; 8, cyst from which young amœbæ are escaping; 9, 10, young free amœbæ; n, nucleus; v, vacuoles.

firmed his statements as regards their etiological significance. The following table summarizes, according to the more recent work of Viereck, Darling,

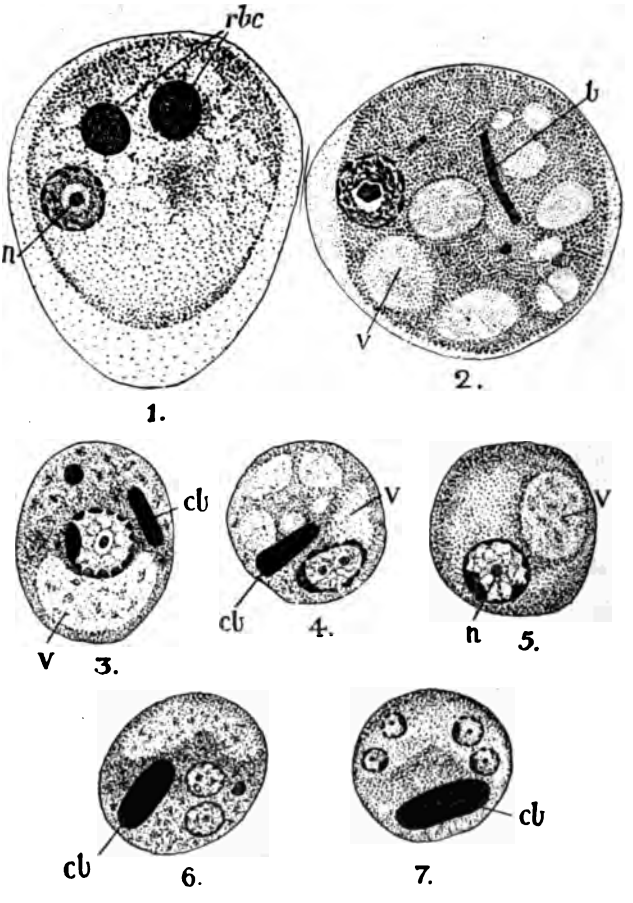


Fig. 79.—Entamœba tetragena (histolytica). (*After Wenyon.*)

1, 2, Free vegetative forms; 3-7, cysts containing one to four nuclei in varying stages of development; n, nucleus; v, vacuoles; c b, chromidial body; b, ingested bacillus; r b c, red blood-corpuscles.

Wenyon, and Walker, the distinctive features of the two species (*see also* Figs. 78, 79):

Entamœba coli. *Size* 15–25 μ.	*Entamœba tetragena* (*histolytica*). *Size* 20–30 μ.
No well-marked distinction between ecto- and endoplasm; latter stains more deeply.	Ectoplasm distinct, much more refractile and more deeply staining than the finely granular endoplasm.
Rarely shows a vacuole.	Usually one or more non-contractile vacuoles.
Rarely contains erythrocytes, crystals, or bacteria, etc.	Often contains large numbers of erythrocytes, crystals, bacteria, etc.
Nucleus sub-central and almost always visible; stains deeply; shows a well marked, rather thick and very refractile nuclear membrane; contains nucleolus and large amount of chromatin.	Nucleus excentric, small, usually indistinct, stains feebly, contains little chromatin, and has no marked nuclear membrane.
Motility very sluggish.	Motility more marked and definite.
Multiplication in the intestine by binary fission. On fæces becoming hard, or outside the body, encystment and formation of eight amœbulæ which are set free when swallowed.	Multiplication in the intestine by fission. * On fæces becoming hard, or outside the body, encystment formation of four amœbulæ which develop when swallowed.

A sexual cycle is not now recognized by most authorities in either species.

While many observers, partly as the result of their own work, but principally it would appear in deference to Schaudinn's great authority, have accepted in the main these descriptions, there are others, notably Musgrave and Clegg, who declare, after careful work extending over several years and carried on in exceptionally favourable circumstances, that they fail to confirm Schaudinn's statements.

In the course of their work Musgrave and Clegg made many important discoveries having a bearing, not only on the etiology but also on the prophylaxis of this type of dysentery. They claim to have shown that under certain conditions what apparently were non-pathogenic amœbæ, collected from a

* Hartmann and Darling have pointed out that Schaudinn's description of reproduction by a process of budding was the result of observing degenerating forms of the amœba.

variety of sources, i.e. vegetables, water, etc., can be made to assume pathogenic properties. Further, following Frosch's methods, they succeeded in cultivating intestinal amœbæ by adding to the cultural media the bacteria usually associated with these amœbæ in the intestine, and which seem to exercise a necessary symbiotic or, rather, metabiotic action, i.e. modify the culture medium in a way favourable to the amœbæ. They have also shown that by gradual habituation amœbæ can be brought to withstand a degree of acidity greatly in excess of that normally present in the human stomach. These observations have not been confirmed, at least as regards the pathogenicity of saprophytic amœbæ. The pathogenic amœbæ have not yet been cultivated.

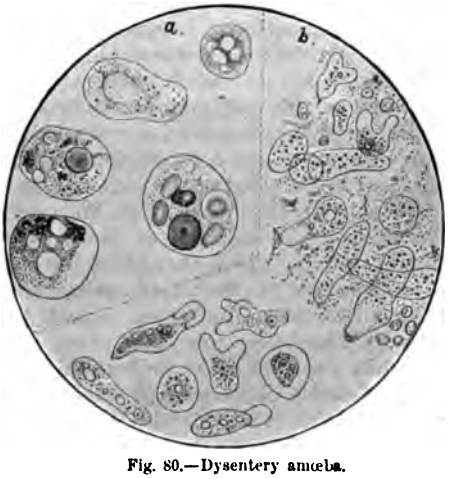


Fig. 80.—Dysentery amœbæ.

a, Amœba dysenteriæ fixed and stained (*Councilman*); *b*, A. dysenteriæ in stools. (*After Lösch, Virchow's "Archiv," Bd.* 65.)

When present in stools, the amœbæ (Fig. 80) are generally easy to find. All the preparation necessary is to pick out a small fragment of stool shortly after it has been passed, and then to lay this on the slide and compress it sufficiently under the cover-glass to form a fairly transparent film. They are said to be most readily found in the watery stools produced by a saline purgative; doubtless because they are washed from off the surface of the bowel by the action of the drug. In hot weather a warm stage is

not required; but in cold weather it is well, until the observer has become by practice familiar with the appearance of the parasite in its passive condition, to warm the slide. This, in the absence of more elaborate apparatus, may be conveniently done by placing the slide on a copper or tin plate with a hole cut in it to allow of the transmission of light. Such a warm stage should be provided with a long arm to the end of which a spirit-lamp is applied, care being taken not to raise the temperature of the slide above blood heat. Search is then made with a half-inch objective. The amœba is a clear, faintly greenish-tinted, transparent body, some three to five times the diameter of a red blood-corpuscle. It is recognized by its movements, which closely resemble those of the ordinary fresh-water amœba. The faintly granular endosarc surrounded by the very clear ectosarc is distinguishable. The nucleus may sometimes be detected in the endosarc, as well as one or two non-contractile vacuoles, and, generally, various extraneous bodies such as blood corpuscles, bacteria, and so forth, which the amœba has included. As the temperature of the slide approaches blood heat the amœbæ send out and retract rounded pseudopodia. These when first protruded consist of ectosarc only; but when the clear protrusion of ectosarc has been extended a little way the endosarc is seen suddenly to burst, as it were, and flow into it. If the temperature of the slide be allowed to fall below 75°F. the parasite will assume a sharply outlined spherical form and remain quite passive until the slide is again warmed up, when the creeping movement may be resumed. In certain specimens heat fails to induce movement, the amœba remaining spherical and passive. The parasite will keep alive on the slide and exhibit movement for an hour or longer.

There can be no question as to the occurrence of this parasite in certain cases of dysentery, but it is not so easy to determine its exact significance in relation to the disease. It is found not only in the mucus lying on or thrown off by the inflamed bowel, but also in the sloughs on the ulcerated surface, in the

tissues constituting the base and sides of the ulcer, and in the still living and relatively healthy tissues for some distance around the lesion, even in the muscular layers, and in the capillaries of the serous coat. This intimacy of association constitutes a good prima-facie reason for regarding the parasite as the cause of the disease. On the other hand, there are many cases of dysentery in which the amœba cannot be found; cases, too, of relapsing dysentery with clinical characters such as are described as belonging to amœbic dysentery. Moreover, as is well known, the amœba, or an amœba which to the clinician is hard to distinguish from *Entamœba tetragena*, is often found in perfectly healthy stools, in cases in which there is no reason whatever to suspect the existence of disease of the alimentary canal.

This occurrence of amœbæ in the stools of healthy individuals, and their absence from the stools in a proportion of cases possessing the clinical characters of the type called "amœbic," have suggested caution in definitely accepting the micro-organism as the true cause of this type of dysenteric disease, and suggest a suspicion that after all it may be merely an epiphenomenon. Evidence, however, is steadily accumulating corroborative of Schaudinn's opinion.

Gasser, in material supplied by 153 cases of dysentery—principally soldiers from Oran—although he found *Amœba coli* in 45 out of 109 acute cases, observed no relationship whatever between the number of amœbæ present in the stools and the severity of the disease. In 34 chronic cases he found the amœba in 13; and in 8 cases of chronic diarrhœa supervening on dysentery he found it in 5. In the stools of 20 healthy individuals from Oran he found the amœba in 4. He further states that he failed to find, or to recognize, the amœba in stained sections of dysenteric bowel. He concludes, therefore, against the amœba having anything more than an accidental relationship to the disease; and that, in place of the amœba causing the dysentery, it is, if anything, the dysentery which causes or, rather, favours the amœba; in other words, that the amœba finds in dysenteric discharges a favourable medium for multiplying in.

Celli and Fiocca studied the parasitology of dysentery in material from 62 typical cases—some from Italy, some from Egypt. They, too, conclude that *Amœba coli* is not a direct cause of dysentery, and for the following reasons:

(*a*) Epidemic, endemic, and sporadic dysentery may occur without amœbæ in the stools. (*b*) Dysentery may be induced by the ingestion, or by the injection into the bowel, of dysenteric fæces which have been ascertained by microscopical examination to be quite free from amœbæ. (*c*) Amœbæ are very common in countries in which dysentery occurs, hence their frequency in the stools of dysenterics in these countries; they are there accidentally. They further point out that *A. coli* is not the only amœba to be found in the intestine; *A. guttula*, *diaphana*, *vermicularis*, *oblonga* and *reticularis*, besides *proteus*, have all been found there. *A. coli* has attracted attention, they consider, principally on account of its movements and size; whereas the other amœbæ, with perhaps quite as good a claim to be considered pathogenic, inasmuch as they can be detected only in specially prepared cultures, elude the eye, even of the sharpest observer, in stools prepared in the ordinary way.

Craig, Vedder, and Hoyt have found cysts of *A. coli* in 70 per cent. of Filipinos and in 50 per cent. of American soldiers in the Philippines—the examinations having been made after the administration of Rochelle salts.

Many attempts have been made to induce dysentery by the injection of animals, or by feeding them with material—stools, liver pus, cultures—containing amœbæ. In a proportion of instances, especially where injections were used, amœbic dysentery has resulted. But as it is impossible to secure the amœba in pure culture, unless it may be in liver pus, these experiments are open to the objection that the successes depended possibly not on the amœbæ present, but on other micro-organisms of a pathogenic nature unavoidably introduced at the same time.

Especially important is one of Schaudinn's experiments. It has a very distinct bearing on the way in which dysentery may be acquired under natural conditions, and as indicating the necessity for the immediate disinfection or destruction of dysenteric stools. Schaudinn fed cats on fresh dysenteric stool without inducing disease; but when he carefully dried the stools at natural temperatures, that is to say, when he had induced the *Entamœbæ tetragenæ* they contained to encyst and form encapsuled spores, and then administered the material to cats, he produced typical amœbic dysentery. In other words, the amœbæ in fresh stool, being in their unprotected vegetative state, were destroyed by the gastric

juice; but their resistant spores in dried stool, not being affected by this secretion, passed on through the stomach, to develop in the lower bowel. This experiment has been amply confirmed, especially by Wenyon and Darling.*

Tetragena cysts are common in the stools of patients during the latent period of the disease, and also in the stools of normal natives (Hartmann), who thus may be regarded as being carriers of the infection.

The intimate connection of abscess of the liver with dysentery, and the presence of amœbæ in the contents of a large proportion of liver abscesses, are now well-ascertained facts, and constitute a powerful, though by no means conclusive, argument for regarding the amœba as an etiological element, if not the probable cause, of amœbic dysentery.

There is yet another circumstance in connection with liver abscess which is not without significance. In a large proportion of liver abscesses the usual pyogenic bacteria are absent. This has been proved over and over again. Cultures made with such pus generally remain sterile. It is a very suggestive coincidence that it is just in those forms of suppurative hepatitis in which the usual pyogenic organisms are absent that this other parasite is present. Moreover, a liver abscess is not like ordinary abscesses; it has no proper abscess wall. Liver pus is not like pus elsewhere; it contains proportionately very few pus corpuscles; but it contains much tissue débris, many blood cells, and much granular matter. As an abscess it is altogether peculiar. A peculiar effect suggests a peculiar cause.

* Lately further confirmation of these experiments has been adduced by Walker and Sellards (*Phil. Journ. Sci.*, Aug., 1913). These investigators induced amœbic dysentery in 4 out of 20 persons by administering vegetative amœbæ from dysenteric stools enclosed in gelatin capsules. In the remaining 16 who did not exhibit dysenteric symptoms, cysts containing four nuclei (*tetragena* cysts) were subsequently found in the stools. Similar experiments with a parallel series of men fed with cultures of several species of free-living amœbæ and also with *Entamœba coli* produced no symptoms whatever, though cysts typical of these species were after a short incubation period found in their stools.

Anyone who has watched the movements of amœbæ on the warm stage can readily understand how such an organism might break down and separate the anatomical elements of a friable organ like the liver, and so cause a softening—a cavity resembling an abscess. It feeds on the tissues, in fact, and to grow and multiply it must disintegrate their structures and consume their cells. Amœbæ occur much more frequently in liver abscess than is generally supposed; a circumstance strengthening the argument for regarding this parasite as being in causal relationship to that lesion, and therefore, *pro tanto*, to dysentery. In support of this statement, I may mention that recently Wenyon has produced not only amœbic dysentery, but also liver abscess in cats by injecting stools containing large numbers of *E. tetragena* cysts, while similar experiments with *E. coli* cysts were uniformly negative.*

Pathology of amœbic dysentery.—The main seat of the ulceration in amœbic dysentery is the large intestine; the small is rarely affected, though the lymphatic glands and liver may be invaded. Single or multiple abscesses of the latter organ are often concomitant features.

It is probable that amœbic lesions unmodified by bacterial action are rarely seen. In nearly every fatal case the mucous membrane is the subject of a secondary bacterial infection, so intense as to destroy all the amœbæ, which can in such cases be demonstrated only in the deeper layers of the intestinal wall.

The ulcers, which are most numerous in the cæcum, hepatic, splenic and sigmoid flexures, may be recognized by their circumscribed, punched-out appearance, the loss of tissue extending down to the muscular coats; the intervening mucous membrane may be normal or show varying degrees of inflammatory change. The coats of the intestine are much thickened; the degree of thickening depending on

* Kruse and Pasquale were able to produce dysentery in cats by means of rectal injection of liver pus containing amœbæ. Harris produced similar results in dogs by the same means, and Gauducheau by introducing liver pus intravenously.

the chronicity of the infection; they may be matted together and adherent to the liver and spleen. The intestines themselves are very friable and easily tear when handled.

In chronic cases polypoid gangrenous tags of mucous membrane hang into the lumen of the gut. The surface of isolated ulcers may be covered with large yellow and gangrenous sloughs. The intestinal contents in these cases are composed of dark, almost black hæmorrhagic fæcal matter possessing a characteristic penetrating odour. Circumscribed areas of the large intestine, or the entire mucosa, may be thus affected, and may then resemble lesions of bacillary origin in which extensive sloughing has taken place. Perforation of the large intestine, resulting in purulent peritonitis, is common. Ulceration of the appendix may also be found. Contractions often leading to occlusion and scars, and pigmentation at the seat of old ulcerations, are commonly encountered in juxtaposition to areas of bowel in which the process is still active.

Microscopic sections through an amœbic ulcer (Fig. 81) reveal amœbæ invading the submucous coat. There are subacute concomitant inflammatory changes. The blood-vessels are dilated. There are no hæmorrhages, but the tissue reaction, as evidenced by invasion by fibroblasts and by round-cell infiltration, is not marked. Red blood-corpuscles may often be demonstrated inside the amœbæ. In more extensive cases, where ulceration has extended into the circular muscular coat, amœbæ may be seen penetrating between the fibres and even inside the dilated capillary vessels of the serous coat.

The adjacent apparently healthy mucous membrane shows comparatively few microscopic changes; there is some round-cell infiltration of the interstitial tissue, into which amœbæ may be seen penetrating and actually lying within the crypts of Lieberkühn. Bacilli can be demonstrated in great numbers in the superficial layers of the ulcer. The amœbæ can be stained in sections by hæmatoxylin and eosin, or by iron hæmatoxylin (*see* p. 519). In

miliary abscesses of the liver amœbæ may be demonstrated lying amongst the necrotic cells; even in inflamed liver tissue which has not yet proceeded to pus formation they may be occasionally recognized.

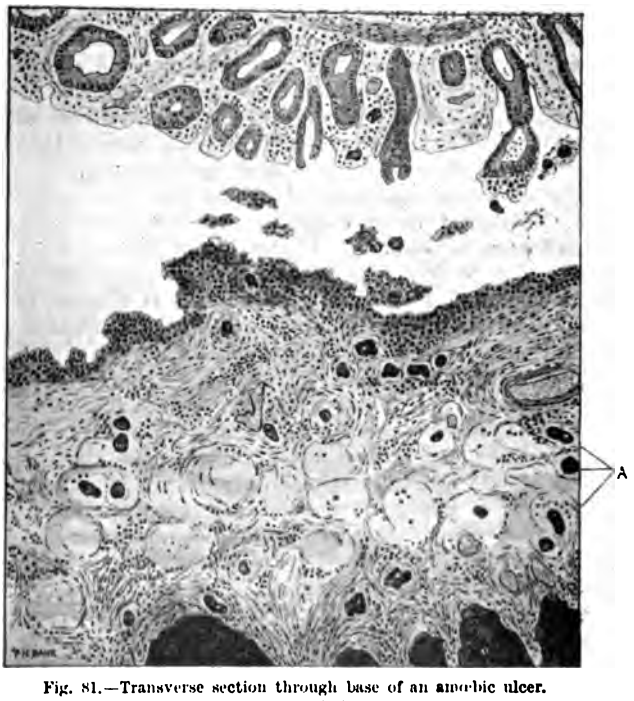


Fig. 81.—Transverse section through base of an amœbic ulcer. (*After Bohr.*)

A, Amœbæ in the submucous layer and invading the mucous membrane where a section passes through a fold of apparently healthy mucosa.

Stained by Heidenhain's iron-hæmatoxylin.

Pathogenic bacilli have not been isolated from the heart's blood or from other organs.

The main points of distinction in the pathology of the two leading forms of dysentery are summarized in the following table :—

Bacillary	Amœbic
An acute diffuse inflammation of the mucous membrane of the large intestine, leading to necrosis and destruction of glandular tissue.	A local lesion of the large bowel, with characteristic ulceration due to penetration of mucosa and submucosa by amœbæ. No diffuse necrosis (except in cases where secondary bacterial infection has taken place).
Ileum often affected.	Ileum rarely affected.
Perforation of intestine and intestinal adhesions rare.	Perforation of intestine and intestinal adhesions common.
In some cases hæmorrhage and destruction of nutrient vessels and infiltration of submucosa to such a degree as to render recovery of function impossible.	Infiltration of submucosa not marked. Local ulceration often extends down to serous coat.
Other organs not implicated.	Liver often implicated.
B. dysenteriæ can be isolated from necrosed mucous membrane and from the stools.	Amœbæ demonstrable in local lesions and in the stools.

As already indicated, mixed infections of both forms may occur.

Balantidium Dysentery

The occasional occurrence of *Balantidium coli* in the fæces, particularly in association with dysenteric diarrhœa, has been recognized for the last fifty years. It is only lately, and more particularly since Strong and Musgrave called attention to the subject, that *B. coli* has come to be regarded as the germ cause of a particular type of colitis resembling in many respects amœbic dysentery. The parasite has been studied zoologically, more especially in temperate climates, but it seems probable that extended observation will show that the balantidium is equally if not more prevalent in warm climates.

Balantidium coli is an oval-shaped ciliated infusorian measuring 0·07 to 0·1 mm. by 0·05 to 0·07 mm. Its anatomical characters may be gathered from Fig. 82. It reproduces by division, budding, and conjugation. Occasionally, losing its cilia, it may become encysted.

How it attains the human intestine is not known, but as it is a common parasite of the pig and apes, in which it occasions a fatal form of dysentery, it is likely that one or other of these animals is a usual source of infection. As attempts to infect animals experimentally have failed, it is reasonable to conclude that the infusorian, on occasion, assumes some resistant form which enables it to withstand the gastric and intestinal juices on the way to its habitat, the end of the ileum and the large intestine. Although it may live for a considerable time in water or fæces (one hour to three days), it has not been grown on culture media. In liquid stools the balantidium exhibits great activity, indulging in locomotive as well as in rotary movements.

Fig. 82.—Balantidium coli.

The symptoms of balantidium dysentery are, in the present state of knowledge, indistinguishable from those of other forms of dysentery. The disease is chronic in type, its special nature being discoverable only on microscopical examination of the stools. Generally only one or two balantidia are found, but as many as twenty may be seen at a time in every field of the microscope.

In the large number of cases collected from different authors by Strong, together with those observed by himself, the mortality amounted to about 30 per cent. In many cases there were no symptoms save occasional diarrhœa. How much of this was due to the parasite and how much to concurrent and independent disease it is difficult to state.

In 30 cases in which autopsies have been made a variety of dysenteric lesions, from catarrhal congestion and diphtheritic patches to extensive ulceration, have been found. On section Strong demonstrated the balantidium not only in exudate on the surface of the bowel, but congregated in large numbers in the follicles, and embedded in the tissues forming the base of the ulcerations, including submucosa and muscular coat, and even in the lumen of blood-vessels and lymphatics. Bowman mentions that the colon is affected in its

whole extent with a mass of ulcers from which hang shreds of necrotic tissue—lesions resembling those of amœbic dysentery.

In the treatment of balantidial dysentery Walker finds from his experimental work that organic compounds of silver are the most effective.

The germs of dysentery often water-borne.—Notwithstanding the vast amount of speculation, time, and work expended in endeavouring to ascertain what the germ or germs of dysentery may be, it cannot be said that as yet we are even near the complete solution of the problem. One thing, however, is fairly well ascertained, and that is that these germs are often introduced by means of drinking-water. The statistically ascertained improvement in the public health in respect of dysentery in such large towns as Calcutta and Madras, following so closely on the introduction of improved water supplies, and the improvement in the health of the British Navy following the introduction of regulations requiring that in all places in which the water supply is not above suspicion the drinking-water served out to the men shall be distilled, constitute powerful testimony in favour of regarding dysentery as a water-borne disease. This conclusion receives additional support from the occurrence of epidemics of dysentery in the crews of ships which have watered at polluted sources, as well as from the occurrence of similar epidemics in large institutions in which, by some accident, surface water has leaked into the water supply. This does not exclude the possibility of other sources of infection, such as privies, dust, flies (especially), fouled vegetables, and the vessels or instruments used by dysenterics.

The germs of dysentery may be fly-borne.—In certain parts of the world—Fiji, for example—where water can be definitely excluded as a source of infection and where extensive epidemics of dysentery are of annual occurrence, it seems probable that the germ is conveyed and diffused by house-flies. Bahr has shown by direct observation that flies fed on

fæcal matter containing dysentery bacilli ingest the germ, which they may subsequently deposit on human food, either in their own fæces, or by regurgitation, or by their soiled feet. This observer associates the annual dysentery epidemics in Fiji with the concurrent enormous multiplication of house-flies, and has isolated dysentery bacilli from the intestinal tract of wild flies caught in the vicinity of patients suffering from the disease. In the case of the dysentery bacillus he has confirmed Graham-Smith's observation on the persistent vitality and virulence of bacilli of the coli group in the intestinal tract of the domestic fly, where they are capable of surviving five or more days.

Predisposing and exciting causes.—It seems not improbable that, in conditions of sound health, the several pathogenic organisms of dysentery may exist in and pass through the alimentary canal without attacking the tissues or giving rise to disease. So long as the mucous surface is sound and vigorous, it has considerable power of protecting itself against many such organisms. It is very probably the same in this respect with the dysentery germ or germs as with the cholera vibrio. Probably it is only on the establishment of some condition of lowered vitality, such as may be induced by catarrhal troubles, chill (a powerful excitant of dysentery), irritating food, bad food, constipation, malaria, scurvy, starvation, and so forth—all well-recognized exciting causes—that the dysentery germ can overpower the natural protective agencies and light up the specific lesions. It is a well-known fact that it is in such circumstances that dysentery is most apt to declare itself. Hence the importance of avoiding these things in tropical climates, more especially in the presence of a bad water supply or of an epidemic.

The **capacity for latency** often exhibited by the germs of dysentery, as of some other intestinal germs, sprue for example, is remarkable. I have encountered cases in which a dysenteric infection (amœbic) contracted in the tropics did not manifest itself for several months after the patient had returned to England. I have also encountered dysenteries that

recurred in England at intervals of one and two years after infection originally acquired in Egypt.

Influence of age, sex, and occupation.—All ages are subject to dysentery. Children are especially liable to the bacillary form, which in them is often fatal. Occupation has no special influence. Both sexes are liable. Pregnancy, miscarriage, and the puerperal state are grave complications.

Diagnosis.—Provided reasonable care be exercised, diagnosis, especially in acute cases, is usually easy. In chronic cases the question of seat worms, hæmorrhoids, polypus, stricture, tubercle, malignant and specific disease, proctitis, ulceration, abscess about the rectum, and tumour in the bowel, may require to be considered. Diagnosis must never be taken for granted. In every case stools must be inspected; and in every case in which there is any probability of rectal disease, some of the methods of digital or specular examination must be carried out. A diagnosis of dysentery having been made, it becomes necessary, especially in view of treatment, to arrive at a correct diagnosis of the type of the particular case. As the practitioner has principally to deal with either bacillary or amœbic dysenteries (very rarely with other forms) he should at once set about ascertaining to which of these two categories it belongs. The following table enumerates the points to be attended to:—

Amœbic Dysentery	Bacillary Dysentery
Clinical.—Insidious commencement as a rule. No fever in uncomplicated cases. Generally subacute or chronic in type. Prone to recur or relapse. Often associated with hepatitis and liver abscess.	Generally acute in character. Often an initial fever. Runs its course and not prone to relapse; one attack confers a certain degree of immunity.
Bacteriological.—No serum reaction. *Entamœba tetragena* in stools.	Serum agglutinates cultures of *B. dysenteriæ*, which can be cultured from the stools on Conradi-Drygalski medium. Absence of *Entamœba tetragena* from the stools.
Reaction to treatment.—Rapidly improves on emetine or ipecacuanha treatment.	Not affected by emetine or by ipecacuanha, but reacts to injection of polyvalent antiserum.

The *Entamœba tetragena* when present is usually easily found in the stools, and is readily recognized by the technique given on p. 505.

Unfortunately, from the point of view of rapid diagnosis, in severe cases of amœbic origin (such as those described by Kuenen and others, and in which gangrenous sloughs are common in the stools) the amœba cannot as a rule be demonstrated during life, though it may be found in sections of the gut post mortem. In such cases it seems probable that the amœba has been removed from the superficial layers of the bowel by a secondary bacillary infection. It is necessary to bear this in mind in view of the specific treatment appropriate to these apparently desperate cases (*see* p. 528). And for the same reason it must not be overlooked that cases of mixed infection with *B. dysenteriæ* and *Entamœba tetragena* do occur; such cases have been reported by Rogers.

In order to obtain permanent preparations it is necessary to fix the amœbæ while still alive; desiccation distorts them to such an extent as to obliterate all their finer structural characters. For this purpose Schaudinn and Wasieliewski have invented a special technique which gives perfect pictures of the nucleus, disposition of protoplasm, vacuoles, etc. The following is a summary of their rather complicated methods:—

Methods for Staining Amœbæ in Stools

1. *Schaudinn's method.*—Can be used either for demonstrating amœbæ in films or an abbreviated form for showing the organisms in sections of tissue. A thin film of the mucus is made on a cover-glass and dropped while still wet, face downwards, into a Petri dish containing a fixing mixture, which should be heated to steaming-point (50° C.).

(1) Fixing mixture. Absolute alcohol, $\frac{1}{3}$; corrosive sublimate, $\frac{2}{3}$; and $\frac{1}{2}$ per cent. glacial acetic; fifteen minutes.

(2) Rinse in weak spirit.

(3) Alcohol 70 per cent.; ten minutes.

(4) Alcohol 70 per cent. and iodine (to dissolve corrosive sublimate); half an hour.

(5) Alcohol 90 per cent.; twenty minutes to one hour.

(6) Through alcohols of decreasing strength to tap-water.

(7) Place *film upwards* in 4 per cent. iron-alum overnight.

(8) Rinse in distilled water and place in Heidenhain's iron-hæmatoxylin solution six to twenty-four hours.

(9) Differentiate in 1 per cent. iron-alum solution under microscope till nuclei of amœbæ are clear.

(10) Pass through increasing strength of alcohols up to

absolute, then two changes of xylol, and mount in Canada balsam.

N.B.—The films must not at any time be allowed to dry.

2. *Wasieliewski's method.*—Wasieliewski has recently (1913) obtained very beautiful specimens of amœbæ stained by Giemsa. The films are made on cover-glasses, fixed in osmic-acid vapour, rinsed in distilled water, and stained with dilute Giemsa (1 : 20 dilution). This method is not so good as the foregoing for demonstrating the nuclear structure.

Isolation of B. dysenteriæ from the stools.—The stool is collected under as aseptic conditions as is possible. A flake of mucus is taken up with a sterilized platinum loop and diluted with sterile normal saline or broth. Some observers prefer to incubate in McConkey's bile broth, which inhibits the growth of all but bacilli of the coli group. Large plates (6-in. Petri dishes) of Conradi-Drygalski medium * (crystal-violet-litmus-lactose-nutrose agar), or of lactose-neutral-red agar,† are then spread in various dilutions and incubated. On Conradi-Drygalski the colonies of the dysentery bacillus are recognizable in twenty-four hours by their transparent blue colour, and on neutral-red-agar by their transparency in contradistinction to the red colonies of *B. coli.* Such colonies often smell strongly of spermin. The bacilli are further recognized by their morphology, their Gram-negative character, their sugar reactions, agglutination tests with the patient's serum and a polyvalent serum, and further by their toxic action on guineapigs when injected intraperitoneally.

In African and West Indian cases the possibility of bilharzia disease of the rectum must be borne in mind, and a microscopical examination made of the urinary sediments and of the fæces. So, too, in cases from the Far East, *S. japonicum* and other intestinal and hepatic parasites must not be forgotten.

In children, especially, intussusception may occur

* The composition of the Conradi-Drygalski medium is as follows: Water, 750 c.c.; lemco, 10 grm.; nutrose, 7 grm.; salt, 3 grm.; peptone, 7 grm.; agar, 20 grm.; litmus solution, 50 c.c.; lactose, 5½ grm.; normal caustic soda (10 per cent.), ¾ c.c.; crystal violet (0·1 per cent. solution), 4 c.c.

† Neutral-red-agar: Agar, 20 grm.; peptone, 20 grm.; lactose, 10 grm.; sodium taurocholate, 5 grm.; water, 1,000 c.c., containing 4 c.c. 1 per cent. watery solution neutral red.

independently, or as a complication of dysentery; the possibility of this must not be overlooked.

Chronic dysentery is often diagnosed chronic diarrhœa or even sprue. This error will be avoided by careful inquiry into the early history of the case, the detection of mucus, of amœbæ, of leucocytes or of red blood-corpuscles in the stools, and the occurrence of tenesmus. Careful inquiry for any history there may be of occasional exacerbations in which straining, and blood and mucus in the stools, are more or less prominent features, will often lead to a correct diagnosis.

Treatment.—The treatment of dysentery requires much judgment and very careful supervision. In former days it was the fashion to bleed repeatedly and to a large amount, and at the same time to administer large doses of calomel—amounting in the aggregate to ounces—and of opium. It is not to be wondered at that the mortality was excessive.

Nowadays better and more rational methods prevail. A most important part of our modern plans has for its object not only the suppression of the germ cause of the disease, but also to afford the diseased organs favourable conditions for repair; not so much to endeavour to heal them as to give them the opportunity of healing themselves.

If called on to treat a case of what appears to be dysentery, our first duty is to assure ourselves that the diagnosis is correct. We must inspect the stools, though unfortunately we cannot differentiate from mere inspection alone to which form the dysenteric stool belongs, and, until the case is quite recovered, we must inspect them daily or frequently. Their condition is the surest guide in the management of this disease. From them we can form a fairly accurate idea of what is going on in the bowel, and from them we can judge of the effects of diet and of drugs.

Importance of rest.—It is with an inflamed bowel as with an inflamed joint: the first and all-important indication to fulfil is, after removing the causes of irritation, to place the part at rest. Could these two indications, the removal of the cause of irritation and the repose of the organ affected, be

fulfilled thoroughly, repair would at once set in. Unfortunately, the affected surface being so inaccessible, we cannot always remove the irritant by directly applied local treatment, nor can we place the parts involved at absolute rest. We can, however, partially meet these indications—quite sufficiently, as a rule, to ensure recovery.

The patient, then, should at once be sent to bed. This in itself has a marked influence on the bowel. Repose must be as nearly complete as possible. The patient must not be allowed to get out of bed; when he has a call to stool he must use the bed-pan. To a certain extent this enforcement of rest is comparable to the placing of an inflamed leg in a splint and elevating it. It ensures some degree of mechanical rest, and relieves the blood-vessels of the inflamed part of a certain amount of hydrostatic pressure.

Food in acute dysentery.—The indication of rest we further endeavour to meet by stopping all solid food. Were it possible, it would be well to stop all food. This, of course, is impossible, and so we make a compromise between the therapeutical indication and physiological necessity by reducing the diet to a minimum and selecting only such foods as, while possessing considerable nutritive value, yield but a small or non-irritating fæcal residue. The tongue is a fair index to the sort of food most likely to suit the case. When this organ is coated, indicating gastric catarrh, small quantities of thin chicken soup, egg albumin, thin barley- or rice-water, are better borne than milk; when the tongue is or has become clean, then milk, pure, diluted with barley- or rice-water, or peptonized, is the best diet. Alcohol is generally contra-indicated, but in cases of collapse small feeds of white wine whey may be given with advantage. These foods should be taken in small quantities at a time, a little every hour or two. They must be given neither hot nor cold, as food when either too hot or too cold is apt to excite peristalsis and to cause colic and straining.

Malaria and scorbutus.—If upon inquiry it is found that there is reason to suspect either a malarial

or a scorbutic element in the case, treatment must be modified accordingly. Careful practitioners never forget to ascertain if these important complicating elements are present or not. If malaria be suspected, or if temperature is markedly raised, it is well to make a careful microscopical examination of the blood for the parasite; if this be found, then quinine must be freely administered either by the mouth or, if the bowels are very irritable, by intramuscular injection. The presence of scorbutus, of course, indicates fruit juices and fresh unboiled milk, in addition to the usual treatment for dysentery.

Drug treatment.—A dose of castor oil and laudanum is a good preliminary in the treatment of dysentery; indeed, many cases are promptly checked thereby, and require no further treatment beyond rest and dieting for a day or two.

The drugs which have proved of most service in the treatment of severe dysentery are ipecacuanha, or its alkaloid emetine, in amœbic dysentery, and one or other of the aperient sulphates either of magnesium or of sodium, opium, and calomel in bacillary dysentery. In this latter variety subcutaneous or intravenous injections of a polyvalent antiserum (Shiga's or Lister Institute) should be administered, together with aperient salines. Until a microscopical examination of the stools has been made it is difficult to prognosticate in any given case whether ipecacuanha, or its alkaloid, is likely to prove the more effective drug, or whether the sulphates or calomel will answer better. In every case one or the other ought to be exhibited at once; one failing after a fair trial, the other, unless manifestly contra-indicated, should get a chance.

Ipecacuanha.—In English practice ipecacuanha is generally the first to be tried. It must be given on an empty stomach. The best plan is to interdict all food for three hours; then to give 10 or 20 drops of laudanum in a tablespoonful of water and, at the same time, to apply a mustard poultice to the epigastrium. About twenty minutes later, when the patient is coming under the influence of the

laudanum, 20 to 30—some give as much as 60—gr. of ipecacuanha in pill, bolus, capsule, or in suspension in about half a wineglassful of water, are administered. With a view to prevent vomiting, the patient is directed to lie flat on his back, using a low pillow, and not to eat, drink, speak, or move for at least four hours. Probably he will fall asleep. Should he feel nauseated, he must as much as possible resist the desire to vomit. With the same object in view, when saliva begins to collect in the mouth, as it is apt to do in such circumstances, it must not be swallowed; on a slight sign from the patient the nurse should remove the accumulating saliva with a handkerchief. If much saliva be swallowed, it is sure to provoke vomiting. In some instances these precautions suffice to avert emesis. Should, however, the ipecacuanha be brought up within an hour of its being swallowed, the dose had better be repeated so soon as the nausea has subsided, the same precautions against vomiting being observed.

After six or eight hours, and when all feeling of nausea has subsided, small quantities of food may be given, and frequent and fractional feeding persisted in for six or eight hours, or until the following day, when the dose of ipecacuanha must be repeated. In many instances one or two such doses abort the dysentery, and the acute symptoms rapidly subside. It is wise, however, to go on with the ipecacuanha once or twice a day for at least a week or longer. It is a good practice to reduce the ipecacuanha by 5 gr. every day. If the drug is doing good, copious fæculent pultaceous yellow stools will be passed after a day or two. This diarrhœa, unless excessive and attended with straining or other dysenteric symptoms, must not be checked or regarded as an indication for stopping the drug.

Thus I wrote in previous editions of this work. My opinion of the value of ipecacuanha is still unshaken, but the use of the crude drug, which is attended by many inconveniences, has been superseded by the use of hypodermic or intramuscular injections of its alkaloid emetine, as advised by

Leonard Rogers. The hydrochloride of emetine is given in doses of $\frac{1}{3}$–1 gr. in distilled water hypodermically up to 1 gr. a day. The stools generally become normal on the third day, but it is advisable to continue the injections for a week or longer. Unfortunately, one course of the drug does not always prevent relapses, but in such cases, if the injections be persisted with, a permanent cure will generally result. In cases where hypodermic injection cannot be made the emetine may be given per os in keratin capsules in 1–2-gr. doses without provoking vomiting, and in very acute or chronic cases in solution by rectal enemata. The hypodermic injection is often followed by slight irritation at the site of injection, but by no more serious symptoms. The intramuscular route is free from this objection. It is advisable to combine the emetine treatment with small doses of some aperient, preferably castor oil.

Rogers's discovery was suggested by Vedder's valuable work on the action of ipecacuanha on amœbæ. Working with cultures of *B. dysenteriæ*, Vedder found that solutions of ipecacuanha had no effect on cultures of that organism, but in cultures of amœbæ he found that a dilution of 1 in 10,000 to 1 in 50,000 was enough to destroy them, though solutions of ipecacuanha sine emetinâ had no deleterious effect. The toxic constituent of the ipecacuanha was thus shown to be the emetine salts; they killed amœbæ in dilutions as high as 1 in 100,000. The physiological action of emetine was ascertained to be negligible; 7·5 gr. failed to produce vomiting when injected into a dog.

Aperient sulphates.—Should ipecacuanha appear to be doing no good, sodium sulphate—which is less irritating than magnesium sulphate—may be tried; indeed, by some this line of treatment is preferred from the outset. These salts have the advantage over ipecacuanha of not causing nausea, and they are often successful. They may be given in drachm doses in a little hot water, or in cinnamon water, every quarter of an hour until a purgative effect is produced; or they may be given in a large dose—half an ounce—to begin with, followed up by smaller doses if necessary. These large doses must not be given when the patient is feeble or in any sense collapsed. Buchanan, speaking from a large

experience of dysentery in Indian gaols, recommends one or two teaspoonfuls of the following stock mixture every one or two hours until free gentle purgation is produced. It should then be continued sufficiently often to secure gentle purgation, and for one or two days after the mucus and blood have disappeared.

℞ Magnesii sulphatis	... ...	℥ij.
Acidi sulphurici dil.	... ...	ʒiij.
Tinct. zingiber. ...	... ...	ʒiij.
Aquæ	... ... ad	℥viij.

If the stools become watery the mixture must be stopped at once. The lessening of tenesmus and the production of copious, soft, fæculent stools are the test of the successful action of the sulphates.

Calomel.—Should these means fail to control the disease, and should the bloody mucoid stools persist and the griping and tenesmus continue, recourse may be had to calomel in combination with opium and ipecacuanha—a grain of each every five or six hours, the effect being watched and salivation avoided. Some give calomel from the outset as a routine treatment in dysentery, either in 5-gr. doses every six or eight hours, or in fractional doses every hour. This method is most in vogue in Germany, and is probably best suited to the bacillary forms of the disease.

Bismuth and opium.—As a result of either line of treatment, the dysenteric symptoms may subside rapidly—perhaps entirely. Sometimes, although the stools become fæculent, and the mucus and blood disappear, diarrhœa remains. This generally quickly yields to a salicylate of bismuth (10–20 gr.) and morphia ($\frac{1}{12}$ gr.) mixture.

Other drugs.—*Simaruba* (*Ailanthus glandulosa*) sometimes succeeds where other measures have failed. It is a drug which, though nowadays neglected in Europe, is still much used in the East by so-called "dysentery doctors." It seems to be specially serviceable when the case has become subacute or chronic. To be effective, it requires to be given in much larger doses than directed in the Pharmacopœias. One method of preparation I have seen

employed is as follows: Using an earthenware pot, boil ½ oz. of simaruba in 1½ pints of water for three hours, and then strain it. Let the patient remain in bed and drink this decoction on an empty stomach every second morning for four times. Food must consist of milk and farinaceous stuffs. Another method is to boil 1 oz. of simaruba in 12 oz. of water until it is reduced to 7 drachms; to this 1 drachm of spirit is added. This preparation, also, must be made in either an earthenware or an enamelled dish. For an adult this is a suitable dose; a child may take a fourth part. It should be taken every night for four nights.* *Kho-sam* (the seeds of *Brucea sumatrana*) is another drug with some reputation as an anti-dysenteric, probably in the amœbic form of the disease.

Monsonia ovata.—Maberly reports favourably on this South African plant in dysentery. He uses a tincture of 2½ oz. of the dried plant to the pint of rectified spirit. It gave in his hands wonderful results, both in acute and in chronic cases which had resisted the ordinary remedies.

Cinnamon, pomegranate, mangosteen rind, and other aromatics and astringents sometimes do good in chronic dysentery.

I can offer no explanation of the action of any of these drugs in dysentery. We use them quite empirically. Ipecacuanha and simaruba have probably a specific action on the disease or on its cause, but in what way it is impossible to indicate with certainty. I incline to think that ipecacuanha, and consequently emetine, have a specific action on the amœba, comparable to that of quinine on the malaria

* Appended is the formula of a preparation of simaruba much used in Shanghai, and there known as "Rhein's Specific Remedy for Diarrhœa and Dysentery." I understand that the formula was purchased by the Shanghai municipality for a considerable sum of money, so highly was it thought of by the European community of that city. Simaruba bark, 3 oz.; Chinese cinnamon, 1 oz.; boil in 3 quarts of water and allow it to evaporate down to 1 pint. When cool, strain into a brandy-bottle, add 3 tablespoonfuls of good brandy, and fill up by pouring cold water over the bark in the strainer till the bottle is full. Dose: A wineglassful three times a day.

parasite or of salvarsan on the pathogenic spirochætes, and that in this way it changes a specific into a simple inflammation. The special rôle of this drug I consider to be amœbic dysentery. Strange to say, ipecacuanha, which has been found so serviceable in India, Africa, the Brazils and elsewhere, has a very poor reputation as an anti-dysenteric in the United States (Osler); it has also signally failed in some English epidemics (Clouston)—facts pointing to specific differences in the dysenteries of different countries.

Intestinal antiseptics.—Salol (10 to 15 gr.), izal, and cyllin in keratin capsules in doses of 60 to 90 minims of pure cyllin per diem, are sometimes followed by good results, especially in the bacillary form of dysentery, if combined with the aperient sulphates.

*Antiserum.** — The intravenous or subcutaneous injection of massive doses (20 to 40 c.c.) of anti-dysenteric sera has been followed by good results, especially in fulminating cases when collapse, due to absorption of the toxins of the dysentery bacillus, has occurred.

A polyvalent serum—that is the serum of a horse immunized against various strains of dysentery bacilli —has given the best results. Such sera are Vaillard and Dopter's, Shiga's, and that of the Lister Institute. The Lister Institute's serum is prepared by injecting a combination of Shiga's, Kruse's and Flexner's original strain, bacilli from El Tor, from asylum dysentery and from infantile diarrhœa. As much as 320 c.c. of this antiserum has been given intravenously within twenty-four hours to desperate cases. In children under 10 years of age 10 c.c. or less is a sufficient dose. The injection is made with a Roux syringe into a large vein and is not followed by any untoward results. Serum treatment should be combined with the general treatment, including intestinal antiseptics and aperient salines. The combination of these three lines of treatment appears to be a rational one. Willmore and Savage report excellent results from El Tor

* The antiserum is put up in phials of 20 c.c. each, which is the usual dose for an adult.

from this line of treatment, and Bahr in Fiji by similar methods reduced the mortality to under 2 per cent. as compared with 13·2 per cent. of a parallel series of cases treated by aperient sulphates alone.

Roux recommends the injection of antiserum as a prophylactic in bacillary dysentery.

In urgent cases in which collapse symptoms are manifest, and where there is no time for a differential diagnosis, it is advisable to combine the emetine and antiserum treatment.

In cases of extreme exhaustion, occasioned by loss of fluid and straining at stool, continuous transfusion with normal saline, in addition to other methods of treatment, is advisable.

Relief of pain.—During the early stages of an attack the patient may suffer much from griping and tenesmus. These are generally relieved by hot fomentations, turpentine stupes, or by a hot bath. An excellent application is the Japanese hot-box or hand-warmer—a small tin box containing a slowly burning cartridge of powdered charcoal. These hot-boxes, or an imitation under the name of *istra*, can now be procured in England. Three or four of them may be roughly sewn into a piece of flannel and laid on the abdomen. This application has the advantage of being very light, of not wetting the clothes, and of keeping warm for many hours. Tenesmus and dysuria are best relieved by morphia hypodermically; or by an enema of a wineglassful of thin starch containing 40 or 50 drops of laudanum; or by suppositories of morphia and cocaine. Washing out the rectum with a pint of very hot water, with or without boric acid, is sometimes effectual in removing for a time, or, at all events, of mitigating, the incessant desire to go to stool and to strain. Two drachms of bismuth with laudanum 30 minims and thin starch 2 oz. is also a good sedative enema.

Treatment should be energetic and thorough at the outset of dysentery. Every effort must be made to prevent it from becoming chronic, as in this stage the disease is very difficult to treat successfully, and is prone to issue in permanent invalidism.

Treatment of chronic dysentery.—As a matter of routine my personal experience leads me to recommend in all cases of chronic amœbic dysentery a preliminary course of ipecacuanha—30, 25, 20, 15, 10 and 5 gr. on successive evenings—with, of course, rest, and a milk and barley-water diet. Thereafter I generally prescribe a minute dose of castor oil, with or without opium, three times a day, regulating the dose according to effects. I may also prescribe a mixture of simaruba and cinnamon, or some intestinal antiseptic, as salol or β-naphthol. Sometimes I continue the ipecacuanha in 5-gr. doses for a month or longer, regarding it as a specific which should be persisted with as we would when giving quinine, iodide of potassium, or mercury. In view of its many manifest advantages, emetine, where available, must now be substituted for the crude ipecacuanha.

These measures failing, I have recourse to some of the following:

Nitrate of silver injections.—The most effective treatment of certain types of chronic dysentery is undoubtedly that by injections of large quantities of nitrate of silver solution of a strength of ½ to 1 gr. to the ounce of distilled water. There is a right and there is a wrong way of using this splendid remedy. If employed in the wrong way, it is useless —perhaps worse than useless. It must never be applied when acute symptoms are present. These must first be got rid of by ipecacuanha, by emetine, by the sulphates, by calomel, by castor oil, and by rest and diet. The patient should be prepared for a week at least in this way. Then the bowel is to be cleared by a small dose of castor oil, followed by a large enema of 3 or 4 pints of warm water to which 2 or 3 teaspoonfuls of carbonate of soda have been added. The whole of this injection having escaped, and when the bowel is quite empty, 2 to 3 pints of the nitrate of silver solution are thrown in by means of a long tube passed slowly and carefully into the bowel as far as it will go without kinking. It is better to fill the bowel by gravitation, using

a funnel and tube, rather than by a syringe. If it seems to be doing good, this injection may be used every few days and kept up for some time. Improvement in suitable cases generally sets in at once. The nitrate, or any other form of enema, must not be persevered with if it causes marked irritation or increase of symptoms.

In the mild chronic dysenteries which are seen in Great Britain, and which originally had been contracted in the tropics, and also in the more acute relapses of tropical dysenteries, ipecacuanha or emetine should always be tried in the way recommended.

Other methods of treating chronic dysentery which succeed at times are the systematic washing out of the bowel daily with warm boric water, with linseed infusion, with milk (a very valuable remedy), with mangosteen rind decoctions, with weak solutions of alum, sulphate of copper, or tannin, with hypochloride of soda solution 1 per cent., with creosote and water or milk—a teaspoonful to the quart; systematic daily dosing with small quantities of castor oil, with or without opium—1 to 2 drachms of castor oil with 4 to 10 drops of laudanum three times a day; 10 to 20 drops of turpentine three times a day; small doses of hydrarg. c. cretâ; the daily consumption of some preparation of fresh bael fruit; a course of Carlsbad, of Kissingen, or of Vichy water; rectal douching as practised at Plombières; a diet of grapes only, of milk only, or of beef only; cold water compresses to the abdomen.

Surgical treatment of chronic dysentery.—When less heroic methods fail and the patient's condition is slowly but progressively deteriorating, right inguinal colotomy or appendicostomy should be offered as affording a reasonable chance. Some time ago I had a colotomy performed in such circumstances with excellent results. If so serious an operation is declined, appendicostomy might be urged. This is easily performed and is not so risky or troublesome as colotomy. A small oblique opening is made through the abdominal wall at the spot usually selected for appendicectomy. The opening should be

large enough to admit two fingers, and the appendix is hooked out; this is easy if no adhesions are present. The appendix is drawn through the wound until its base is in contact with the parietal peritoneum, and it is then fixed in this position by a stitch of fine silk or catgut passing through the meso-appendix and the adjacent cut edge of the peritoneum. The appendix is opened immediately or in a few days' time. The cæcum and colon may now be washed out through the appendix as frequently as desired. For this purpose a No. 8 rubber catheter with a copper stilette is employed, and a rectal tube with an outflow tube. The patient should lie on his back; should the cæcum get distended and the fluid fail to pass freely, turning him slightly to the left will restore the flow.

Post-dysenteric constipation.—After the subsidence of a dysentery, constipation and balling of the stools is by no means an uncommon event. This complication is best prevented, or met, by enemata of warm water to which a little salt—a teaspoonful to the pint—has been added, or, if the bowel is very irritable, of linseed tea or of thin rice-water. An occasional dose of castor oil, half to one teaspoonful, once or twice a week or oftener, and kept up so long as the motions are not quite healthy, is an excellent routine practice; its action may be supplemented by a glycerine suppository. A course of Carlsbad waters or Carlsbad salts often gives excellent results.

Food and clothing.—In chronic dysentery much attention should be given to clothing and food. The former should be very warm. Dysenterics ought never to feel cold. Cold bathing is very dangerous for them; so are alcoholic drinks of all sorts. Food should be simple in the extreme. Beef, mutton, cheese, bread, coarse fruit or coarse vegetables, nuts, pickles, and such-like are, as a rule, not well borne. Fruit and fine well-cooked vegetables in moderation are necessary and often beneficial. In obstinate chronic dysentery it is often a good thing to change the diet from slops to solids, from a meagre to a more

liberal one. The quantity of food is as important as the quality. Chronic dysenterics should eat no more than suffices to maintain their weight. Large meals must be avoided, and food should not be taken unless there is appetite. Monotony of food should be guarded against. Wonderful results are sometimes got from a sea-voyage.

Hepatitis.—During the whole course of an attack of dysentery, and for months thereafter, the condition of the liver must receive the most careful attention. We may not be able to prevent abscess of this organ; but if pain and swelling seem to suggest it as threatening we can try by means of full and repeated doses of ipecacuanha, emetine, saline aperients, rest, low diet, fomentations, dry cupping, and similar measures to avert what, to say the least, is a very grave complication.

Prophylaxis.—The prophylaxis of dysentery consists principally in securing a pure water supply; in avoiding unwholesome or contaminated food; in temperance; in clothing warmly and avoiding chill; in correcting constipation and stopping diarrhœa; and, in public institutions such as gaols and asylums, in regarding dysentery as an infectious and readily communicable disease, in strictly isolating patients suffering from symptoms of colitis, or even looseness of the bowels, and in careful sanitation, directed towards the disposition of fæcal matter and the suppression of house-flies.

CHAPTER XXX

EPIDEMIC GANGRENOUS RECTITIS

So far as known, this very fatal disease seems to be confined to the natives of the low-lying, hot, damp regions in the north of South America, and, perhaps, to the natives of Fiji and other islands of the South Pacific. In Guiana it is known as "caribi" or "Indian sickness," in Venezuela as "bicho" or "el becho." It is said to be very contagious, and appears to be a form of rapidly spreading phagedæna, which starts from the neighbourhood of the anus. Occasionally it may begin higher up—in the colon. In the latter case it is called the "high" form; in the former, the "low" or rectal form. Animals as well as men are attacked.

I am indebted to Dr. Ackers, of Curaçoa, formerly of Venezuela, for the following information on the subject:—"I have only seen cases of the disease in animals, principally fowls, though also in dogs and calves; but I have been told by medical men, who themselves attended the cases, of its occurrence in children of the poorer classes. The disease commences by an itching in the anus, which produces an inclination to frequent defæcation. This stage continues for a few days, when a severe inflammation of the mucous membrane of the rectum sets in, giving rise to symptoms of acute dysentery. There are frequent stools of a mucous, bloody substance, accompanied sometimes by bile or excrement; at the same time there is much straining, considerable elevation of temperature, anorexia, and great thirst. At this period, if the animal or child is not attended to, the above symptoms become more alarming; a constant flow of a slimy, fetid, semi-liquid substance streaked with blood appears. Sometimes the discharge is of a bright-green colour, such as might be obtained by

crushing tender stalks of grass. When this occurs the patients refuse all food, but the thirst is still intense. The affected animal remains standing in one place, with drooping head, as if overcome by fever and weakness. For a day or so it continues like this, until at last, unwilling to move, eat, or even drink, it suddenly dies in convulsions. Sometimes, however, this stage is not fatal, but is followed by prolapsus of the rectum, which is in a very inflamed state and ulcerated; rapidly gangrene sets in and is quickly fatal. The Venezuelan peasants state that this disease arises in children from chewing the green tender stalks of unripe maize, of which they are very fond on account of its sweetness. In children prolapsus of the rectum is very frequent; in bad cases they may die, like the animals, in convulsions, though in children convulsions are not necessarily a fatal symptom. The treatment employed by the natives for animals consists in an enema of strong lemon juice, mixed with a weak dilution of white rum and water (aguardiente), two or three times a day; at the same time, the anus is freely dusted with wood ashes, some of which are also introduced into the rectum. A purgative of oil is generally administered also. In some cases I have known this treatment prove very successful. On the other hand, when the disease is far advanced, or when the ulceration of the bowel appears at an early date, it seems to be of little or no avail. Another treatment employed, especially for children, consists in an enema of the juice obtained by crushing the stalks and leaves of *Spigelia anthelmintica* (pasote). A decoction of the same herb is also given by the mouth three or four times a day. This decoction is very frequently administered by the peasants as an anthelmintic. In cases of children suffering from 'bicho,' one of the quarters of a lemon is roasted and introduced into the rectum as a suppository once or twice a day, and I have heard that it gives very satisfactory results."

CHAPTER XXXI

HILL DIARRHŒA

Definition.—A form of morning diarrhœa accompanied by flatulent dyspepsia and the passage of copious liquid, pale, frothy stools. It occurs principally in Europeans on their visiting the hills after residing for some time in the hot lowlands of tropical countries.

Geographical and seasonal distribution.—Crombie, who gave an excellent account of this disease, pointed out that a similar affection may show itself in the highlands of Europe as well as in those of India. It is said also to occur in corresponding circumstances in South Africa and South America. There is no reason, therefore, to suppose that hill diarrhœa is special to India, although, owing to the large European population frequenting the hill sanitaria in that country, it has been particularly noticed there. An elevation of 6,000 feet or over, when combined with an atmosphere saturated with watery vapour, is particularly favourable to its development. In India it is found to begin and end with the rains, during which, in certain years and places, it is apt to assume almost epidemic characters. Thus, during the wet season of 1880, in Simla an epidemic of hill diarrhœa affected from 50 to 75 per cent. of the population, three-fourths of the cases happening within a week of each other. In some years hill diarrhœa is less prevalent than in others; but at the proper season few of the various hill sanitaria of India are without examples.

Etiology and pathology.—It is difficult to say what may be the precise factors determining this disease. The low barometric pressure associated with great elevation above the sea-level may be a favouring circumstance. Damp seems to be indicated by the

fact that the disease occurs principally during the rains. Chill after exposure to the high temperature of the plains has possibly an important share. Manifestly there is a suspension of the functions of the liver and, considering the dyspepsia and looseness, most probably of those of the pancreas and of the other glandular structures subserving digestion. Hill diarrhœa is certainly something more than an intestinal catarrh. As Crombie pointed out, it is more in the nature of dyspepsia. There are no adequate grounds for connecting it with either the water or the food supply. The question of micro-organisms has, apparently, not been studied.

Symptoms.—Without very obvious cause the patient, who in other respects may be in good health, soon after arrival at a hill sanitarium becomes subject to a daily recurring diarrhœa, the looseness coming on regularly every morning some time between 3 and 5 o'clock. The calls to stool are apt to be sudden and imperative. The motions passed are remarkably copious; very watery in some instances, pasty in others. They are pale, frothy, and like recently stirred whitewash, so devoid are they of biliary colouring matter. Their passage is attended with little or no pain, often with a sense of relief. From one to half a dozen, or more, such stools may be voided before 11 a.m. After that hour, at all events in ordinary cases, the diarrhœa is in abeyance for the rest of the day, and the patient may then go about his duties or pleasures without fear of inconvenience.

The distinctive features of this form of diarrhœa are, therefore, the regularity of its recurrence every morning and its cessation after a certain hour in the forenoon; the absence of colour in the stools; and the attendant flatulence. The abdomen is sometimes blown out like a drum, the patient being conscious of unpleasant borborygmi associated with a feeling as of some boiling or chemical operation proceeding in his inside. Occasionally cases are met with in which the stools are very pale although there is no diarrhœa.

Under treatment, or spontaneously, or, according to Crombie, on acclimatization occurring, after some

days or weeks the diarrhœa may subside. In other instances it persists, in defiance of treatment, until the return of the patient to the warm plains, when it at once spontaneously subsides. Crombie instanced a case in which the patient was regularly attacked with hill diarrhœa whenever he visited Simla—twelve occasions—recovery invariably taking place on his return to the plains. If the looseness is both considerable and protracted, there necessarily ensue debility, wasting, and anæmia, and the disease may lapse into confirmed sprue—an affection having, apparently, close affinities with hill diarrhœa.

Treatment.—The treatment recommended by Crombie, and endorsed by other medical men of experience in India, consists in a pure milk diet, rest, warm clothing, a teaspoonful of liquor hydrargyri perchloridi in water about fifteen minutes after food, and 12 gr. of pepsine, or a corresponding quantity of lactopeptine or ingluvin, two hours later. If, in spite of treatment, the disease persists, the patient must return to the low country.

CHAPTER XXXII

SPRUE (PSILOSIS)

Definition.—By the term "sprue" is understood a peculiar and very dangerous form of chronic catarrhal inflammation of the whole or part of the mucous membrane of the alimentary canal, generally associated with disturbance of the chologenic function of the liver and, probably, of the functions of the other glandular organs subserving digestion. Although a disease of warm climates it may develop for the first time in temperate climates; only, however, in individuals who have previously resided in the tropics or sub-tropics.

Sprue is characterized by irregularly alternating periods of exacerbation and of comparative quiescence; by an inflamed, bare, and eroded condition of the mucous membrane of the tongue and mouth; by flatulent dyspepsia; by pale, phenomenally copious, and generally loose, frothy, fermenting stools; by wasting and anæmia; and by a tendency to relapse. It may occur as a primary disease, or it may supervene on other affections of the bowels. It is very slow in its progress; and, unless properly treated, tends to terminate in atrophy of the intestinal mucosa, which usually, sooner or later, proves fatal.

Nomenclature.—Sprue has been more or less recognized by writers on tropical medicine for many years. It has been called "tropical diarrhœa," "diarrhœa alba," "aphthæ tropicæ," "Ceylon sore mouth," "psilosis linguæ" (Thin), besides a variety of other names. The term "sprue" is an adaptation from the Dutch word *spruw* in use in Java, where the disease is very common.

Geographical distribution.—It is probable that sprue, although more common in certain warm countries than in others, is found throughout the

greater part of the tropical and many parts of the sub-tropical world. It is especially common in South China, Manila, Cochin China, Java, the Straits Settlements, Ceylon, India, tropical Africa, the West Indies (Hillary), and Porto Rico (Ashworth). Apparently it is most prevalent in those tropical countries in which prolonged high temperature is combined with a moist atmosphere. It is common, however, in certain sub-tropical countries, as North China and even in Japan ; countries where, although the summer is hot and damp, the winter is dry and bracing.

Etiology.—Prolonged residence in the endemic area is, perhaps, the most potent predisposing influence; cases, however, do occur in which the disease shows itself after a residence of one or two years only. Exhausting diseases, particularly those involving the alimentary canal, as dysentery, hill diarrhœa, morning diarrhœa, hæmorrhoids and fistula, are apt to terminate in sprue. Frequent childbearing, miscarriages, uterine hæmorrhages, exhausting discharges, and prolonged lactation also predispose to the disease ; so may syphilis, courses of mercury or of iodide of potassium, bad food, bad water, anxiety, chills, and so forth—in fact, any depressing influence, particularly if it is combined with intestinal irritation. Malaria does not seem to be specially responsible. At one time *Strongyloides intestinalis* (*Anguillula intestinalis*), a parasite very common in the stools of cases of chronic intestinal flux, particularly in Cochin China, was put forward as the cause of the chronic entero-colitis (for the most part sprue) of that country. Subsequent investigations have disproved this. Like the anguillula, *Amœba coli* or *Bacillus dysenteriæ* may be present in the stools in these cases; but, similarly, they are in no way responsible for the disease. Neither has any bacterium, or fungus, or other micro-organism which can be regarded with any degree of certainty as special to sprue been separated from the characteristic stools.

Formerly sprue was supposed to be peculiar to the European in the tropics; but Bahr has recently shown that it is by no means rare in the descendants

of the early Dutch settlers in Ceylon, and in the native Cingalese and the immigrant Tamils. He has also brought forward evidence tending to show that it is an infective disease.

In searching for the fundamental cause of this affection, the latency which the disease occasionally exhibits, and the fact that the first symptoms may not appear until months or even years have elapsed since the patient quitted the tropics, must be kept in view.

Symptoms. *Variability.*—There is infinite variety in the combination and in the severity of the various symptoms of sprue, as well as in the rate of progress of the disease. In some instances it may be almost a subacute process running its course in a year or two; in others, again, it may drag on intermittingly for ten or fifteen years. Much depends in this respect on the circumstances, the character, the care, the treatment, the age and the intelligence of the patient.

General symptoms in a typical case.—In an ordinary fully developed case the patient—who is generally dark or muddy in complexion and much emaciated—complains of three principal symptoms: soreness of the mouth, dyspeptic distension of the abdomen, looseness of the bowels; the last being particularly urgent during the early morning and part of the forenoon. The patient may also complain of feeling physically weak, of loss of memory, and of inability to take exercise or to apply his mind. His friends will probably volunteer the information that he is irritable and unreasonable.

Mouth lesions.—If the mouth is examined, the soreness will be found to depend on a variety of lesions of the mucous membrane, which, though painful, seem to be of a very superficial character. These lesions vary considerably in intensity from day to day. During an exacerbation the tongue looks red and angry; superficial erosions, patches of congestion, and perhaps minute vesicles appear on its surface, particularly about the edges and tip. Sometimes, from the folding consequent on swelling of the mucous

Acute stage. (*After Thin.*)

Chronic stage. (*After a painting by P. H. Bahr.*)

Sprue tongue.

PLATE IX.

[illegible]

[illegible]

[illegible]

and may persist for years before the characteristic diarrhœa supervenes.

Dyspepsia.—Dyspepsia is usually much complained of, the feelings of weight, oppression, and gaseous distension after eating being sometimes excessive. Very likely the abdomen swells out like a drum, and unpleasant borborygmi roll through the bowel. Occasionally, though not often, there may be vomiting, the vomiting sometimes being sudden and not always accompanied by feelings of nausea.

Diarrhœa.—The diarrhœa associated with sprue is of two kinds—one chronic and habitual, the other more acute and, in the early stages, evanescent. The former is characterized by one or more daily discharges of a copious pale, greyish, pasty, fermenting, acid, mawkish, evil-smelling material. The latter is of a watery character, also pale and fermenting, the dejecta containing undigested food and, usually, an abnormally large amount of oil and fatty acids. In these latter circumstances the diarrhœa usually brings with it considerable relief to the dyspeptic distension, at all events for a time. When the mouth is inflamed the diarrhœa is usually more active. The stools during periods of quiescence may be confined to one or two in the early morning or forenoon; during the later part of the day the patient is not disturbed. The stools, however, even in this quiescent phase, are always extraordinarily copious, the excessive bulk being attributable in great measure to the aforementioned excess of fat and the innumerable microscopic gas bubbles; patients remark their phenomenal abundance. They are passed almost, or altogether, without pain. Not infrequently during exacerbations there may be a tender excoriated condition of the anus, and sometimes, in women, a similar condition of the vagina.

Types, history, course, and termination. Protopathic sprue.—There is a striking uniformity in the history of most cases of sprue. On inquiry, we shall probably learn that the patient has been suffering for months, or perhaps years, from irregularity of the bowels. This, we may be told, began soon after

arrival in the tropics as a bilious morning diarrhœa. For a long time this morning diarrhœa went on, without interfering in any way with the general health. Later the mouth, now and again, became tender, little blisters or excoriations appearing for a day or two at a time about the tip of the tongue or inside the lips. These sore spots would come and go. Perhaps, from time to time, exacerbations of the mouth symptoms would be associated with a little increase of diarrhœa. Gradually the stools lost their bilious character and became pale and frothy; dyspeptic symptoms, particularly distension after meals, now appeared. As time went on, these symptoms would recur more frequently and in a more pronounced form, following, almost inevitably, any little imprudence as regards food or exposure. The general condition now began to deteriorate; emaciation, languor, lassitude, and inability to get through the day's work satisfactorily becoming more pronounced each summer until, finally, a condition of permanent invalidism was established. Should the disease continue to progress, the emaciation advances slowly but surely. Diarrhœa may be almost constant, and now no longer confined to the morning hours; the complexion becomes dark, sometimes very dark; the appetite, sometimes in abeyance, is more frequently ravenous, unusual indulgence in food being followed by increased discomfort, temporarily relieved by smart diarrhœa. At length the patient is confined to the house, perhaps to bed. The feet become œdematous, and the integuments hang like an ill-fitting garment, the details of the bony anatomy showing distinctly through the dry, scurfy, earthy skin. Finally, the patient dies in a semi-choleraic attack; or from inanition; or from some intercurrent disease. Such is the history of an ordinary, mismanaged case of sprue.

Sprue secondary to dysentery.—When the disease has supervened on dysentery, we learn that the motions characteristic of the original dysenteric attack had gradually changed in character; from being scanty, mucoid, bloody, and accompanied with pain and tenesmus, they became diarrhœic, pale,

frothy, their discharge being followed by a feeling of relief rather than of pain. The mouth at the same time became sore, exhibiting the characters already described. Gradually a condition of confirmed sprue was established, which ultimately, unless properly treated, will almost certainly prove fatal.

Sprue secondary to acute entero-colitis.—Another type of case commences as an acute entero-colitis with sudden and profuse colicky diarrhœa, vomiting perhaps, and a certain amount of fever. The acute symptoms do not subside completely, but gradually have the typical symptoms of sprue grafted on to those of an acute intestinal catarrh.

Incomplete sprue. (*a*) *Gastric cases.*—Occasionally we meet with cases of confirmed sprue in which, at first, the morbid process, judging from the existing clinical symptoms and subsequent history, is confined to a limited part of the alimentary canal. Thus we sometimes get sprue without diarrhœa, the principal symptoms being sore mouth, dyspeptic distension, pale copious but solid stools, and wasting.

(*b*) *Intestinal cases.*—On the other hand, we may get cases in which the mouth is not eroded, and in which there is little or no distension or dyspepsia, but in which the stools are liquid, copious, pale, and frothy. Sometimes a patient who may have suffered at an earlier period or on a former occasion from the first type of the disease, later acquires the diarrhœic form; and vice versa.

(*c*) *Sprue without diarrhœa.*—It sometimes happens that under treatment the sore mouth, the dyspepsia, and the diarrhœa completely subside; nevertheless the wasting continues, the stools remaining phenomenally copious—so much so that the patient may declare that more is passed than has been eaten. In this case wasting is progressive, and the patient gradually dies of inanition.

Intestinal atrophy consequent on sprue.—In certain instances, under treatment the symptoms proper to sprue subside; but the patient's digestive and assimilative faculties are permanently impaired. Slight irregularities either in the quality or the

amount of food, chill, fatigue, depressing emotions, and other trifling causes suffice to bring on dyspepsia accompanied by flatulence and diarrhœa. These cases may linger for years. Usually they improve during the summer in England, getting worse during the winter and spring, or during cold, damp weather. Ultimately they die from general atrophy, diarrhœa, or some intercurrent disease.

Morbid anatomy.—Post mortem the tissues in sprue are abnormally dry; fat is almost completely absent; the muscles and the thoracic and abdominal viscera are anæmic and wasted. With these exceptions and certain important changes in the alimentary tract, so far as known there are no special lesions which are invariably associated with this disease. According to Bertrand and Fontan, occasionally certain changes are present in the pancreas—namely, fatty or granular degeneration of the cells, with softening of isolated acini and slight inflammatory infiltration of the connective tissue. These, however, are not more constant than are certain other and similar changes occasionally found in the liver and kidneys. Sections of the tongue show desquamation of the epithelium, especially from the surface of the fungiform papillæ; an invasion of the epithelial cells by yeast fungi has been shown by Kohlbrügge to take place and is possibly a terminal infection.

Lesions of the alimentary tract.—The principal and characteristic lesions are found in the alimentary tract. The bowel is thinned to such an extent as to be almost diaphanous. The serous coat is generally healthy, the muscular coat atrophied. The submucosa in places has undergone hypertrophic fibrous changes; and the mucous membrane from mouth to anus, either in patches or universally, is superficially eroded and interstitially atrophied. The internal surface of the bowel is coated with a thick layer of dirty grey, tenacious mucus containing numerous yeast cells and branching mycelium (Bahr), which conceals patches of congestion, of erosion, or even of ulceration, besides such evidences of similar antecedent

disease as pigmented areas and thin-scarred, cicatricial patches. The villi and glands are eroded and in many places completely destroyed. Here and there minute spherical indurations, about the size of a pin's head

Fig. 83.—Transverse section of ileum in case of sprue, showing partial loss of columnar epithelium (probably a post-mortem change), shrinkage of villi, round cell infiltration, fibrosis of submucosa, and dilatation of nutrient vessels of submucosa.

and surrounded by a dark pigmented or congested areola, can be felt in the mucous membrane. On cutting into these, they are found to be minute cyst-like dilatations of the follicles filled with a gummy, muco-purulent material. Sections of the diseased bowel (Fig. 83) show under the microscope corre-

sponding changes, such as varying degrees of erosion or ulceration of the surface of the mucous membrane; degeneration of villi, glands, and follicles; the small mucous cysts referred to; sometimes small abscesses; and, also, infiltration by leucocytes of the basement membrane and submucous layer; and, in the latter, fibro-cirrhotic changes. The mesenteric glands are generally large and pigmented, perhaps fibrotic. The erosion lesions are usually most marked towards the end of the ileum and in the colon; but they may be present in greater or lesser degree universally, or in patches throughout the entire alimentary tract from mouth to anus.

Pathology.—In attempting an explanation of the phenomena of sprue, two features of the disease have to be considered—the catarrhal condition of the alimentary canal, and the absence of the normal colouring matter of the fæces. Possibly one of these is the consequence of the other; possibly the two conditions are concurrent but independent consequences of the same cause. What that cause may be is quite unknown. Whether the first pathological step originates in physiological exhaustion of the digestive functions, brought about by tropical conditions; or whether the disease depends upon a specific organism; or whether there is a combination of these, has still to be settled. In view of the occurrence of morning diarrhœa of dark bilious stools as a frequent first step in the development of sprue, hyperactivity of the liver might be assumed to be a first step in the development of the disease, an activity which in time ends in exhaustion of the chologenic functions of the gland. It might be further suggested that concurrently with this hepatic disturbance there is a similar initial hyperactivity of all the other glands appertaining to digestion, a hyperactivity which also ends in a corresponding exhaustion. Chemical changes in the ingested food would then follow on the establishment of these apeptic conditions, and ultimately, from the formation of acrid chemical bodies, lead to the chronic catarrhal changes found post mortem.

Analyses of the stools in sprue by Wynter Blyth, Hunter, v. der Scheer, Harley and others resulted in ascertaining the presence of the ordinary elements of bile, notwithstanding their apparent absence so far as lack of colour would indicate. Bile is secreted, but the colouring matter, bilirubin, is not formed, or is changed in the intestine into a colourless substance, leuco-urobilin (Nencki). The excess of fat in the stools would indicate pancreatic disease or destruction of the lacteal capillaries.

Of course, micro-organisms, and especially yeast fungi, abound in the fermenting stools; but hitherto no bacterium or protozoon which could be regarded as specific has been found in association with the disease.

Personally, I incline to regard sprue as the result of a specific infection falling upon structures subserving digestion, exhausted from over-stimulation by certain meteorological conditions. The remarkable effect of physiological rest, as supplied by "the milk treatment," in curing sprue, the relative rarity of the disease in the natives of the endemic area, the occasional latency of the disease, and the tendency to relapse seem to support this hypothesis.

Diagnosis.—The condition of the tongue, the character of the stools, and the history are sufficiently distinctive, one would suppose, to render diagnosis an easy matter. Nevertheless, I have known of cases in which the disease has been diagnosed and treated as syphilis, the condition of the mouth being attributed to this disease, the character of the stools and other symptoms being ignored. Care must be exercised in interpreting the significance of the small area of liver dullness usually found in well-marked cases of sprue. This is not due to cirrhosis of the liver, but to the wasting this organ undergoes in common with the rest of the soft tissues of the entire body. The absence of skin lesions and mental symptoms differentiate sprue from pellagra.

Prognosis is good for recent cases, provided proper treatment is carried out. It is bad for patients over 50, for long-standing cases, for careless

and injudicious patients, and for those who cannot or will not take a purely milk diet.

Treatment. *Importance of early and thorough treatment.*—If treatment be undertaken sufficiently early in sprue, and be thoroughly and intelligently carried out, it is generally marvellously successful. Should, however, it be undertaken at too late a period, when the glands and the absorbing surface of the alimentary canal have been hopelessly destroyed, do what we will the case is sure to end fatally. In prescribing a treatment, therefore, the first thing for the physician to do is to get his patient thoroughly convinced of the deadly nature of his complaint; for, unless he receives the hearty and complete co-operation of his patient, the physician must not expect to cure a well-established case. To be successful, treatment must be thorough, sustained, and prolonged. All predisposing causes, as uterine or other discharges, syphilis, scurvy, and the like, must of course be dealt with and, so far as possible, removed.

The milk cure.—By far the most successful treatment is what is known as the "milk cure." In carrying this out it is well to commence with a dose of some aperient—castor oil or pulvis rhei compositus. Pending the action of the drug, all food, including milk, should be withheld. The patient should be sent to bed in order to economize strength and maintain an equable warm temperature of the skin. He should also be directed to clothe warmly, to encircle the abdomen with a broad flannel binder, to cover his arms and shoulders with a warm jacket, and to live in a large, sunny, warm room. When the purgative has acted the milk is begun. At first 60 oz. at most are allowed in the twenty-four hours, small quantities being given every hour or every two hours. When the patient is very weak the feeding must be continued during the night. *The milk should not be drunk, but sipped with a teaspoon, or taken through a straw or fine glass tube, or from a child's feeding-bottle.* As a rule, on this regimen, in the course of two or three days, the patient's condition is very

much improved. The stools have increased in consistency — are solid perhaps, the distension of the abdomen has subsided, dyspeptic symptoms have vanished, and the mouth is much less tender and less inflamed. The quantity of milk should now be increased at the rate of half a pint a day or every second day, until 100 oz., or thereabouts, are taken in the twenty-four hours. It is well to keep at this quantity for ten days at least, when, everything going well, a gradual increase to 6 or 7 pints may be sanctioned. Up to this point the patient should keep in bed; but when he has reached this quantity he may get up and, if he feels strong enough and the weather is mild, go out of doors. *For six weeks, dating from the time the stools become solid and the mouth free from irritation, no other food or drink whatever should be permitted.* A raw egg, if it is found to agree, may now be added to the milk; later, some artificial malted food; next, small quantities of well-boiled arrowroot, rusks, pulled bread, thin bread (stale) and butter, or other digestible form of starchy food; later still, chicken broth, a little fruit; and, by and by, fish and chicken may be gradually introduced.

Importance of prompt treatment of threatened relapses.—Should, however, the slightest sign of dyspepsia or flatulence, especially of diarrhœa, or of sore mouth show itself, then the extra food must be discontinued immediately, a dose of compound rhubarb powder or castor oil administered, and the patient be sent back to bed and placed once more at absolute rest and on a pure milk diet. In convalescents, no matter how long the acute symptoms have been in abeyance, this prompt recognition and treatment of threatened relapse should be rigorously observed. This is a rule of the utmost value and importance. Procrastination in treatment, under these conditions, is exceedingly dangerous. Promptitude in recognizing and treating relapse not only saves time, but it may avert hopeless intestinal atrophy.

Symptoms persisting.—In commencing this treatment, if the patient after two or three days be

found unable to digest and assimilate so much as 3 pints of milk in the twenty-four hours, the daily allowance must be reduced by half a pint a day until 30 oz. or thereabouts only are taken. If now the motions become solid, the quantity of milk must be gradually increased by 5 or 10 oz. a day, so that in the course of a few weeks the full allowance—6 or 7 pints—is consumed.

How to meet inadequate assimilation.—It sometimes happens that the quantity of milk can be raised to 70 or 80 oz. per diem, but no higher, further increase bringing on sore mouth, distension, and diarrhœa. In some of these cases the difficulty appears to depend not so much on digestion as on inability to absorb a large quantity of fluid. Occasionally, in such cases, one may succeed in getting the necessary amount of nutriment introduced by thickening the milk with condensed milk; or by slowly evaporating fresh cow's milk so as to reduce its bulk without diminishing the solids (Thin). The evaporation is best done in a vessel like a glue-pot, in which the milk is not boiled, but is surrounded by a jacket of boiling water; the milk during the process must be constantly stirred to prevent the formation of a scum. Or the milk diet may be supplemented by an adequate allowance of raw or underdone meat.

Other forms of giving milk.—Digestion is sometimes aided by peptonizing the milk; or by mixing it with lime water or a little salt; or by aerating it in a soda-water siphon. Koumiss sometimes agrees for a time when ordinary milk fails, and, if necessary, should be tried. Similarly, white wine whey is occasionally digested when milk is not; it is often of great service, especially when an alcoholic stimulant is indicated.

Fruit treatment.—The value of fruit in the treatment of sprue and other forms of intestinal disease has long been recognized by a limited number of practitioners, particularly abroad. It is only lately that it has obtained any hold on medical opinion in England. I have long been in the habit of prescribing bananas and apples, tentatively of course, in

these cases, and often with marked success. Of late repeated trials of the strawberry in sprue have confirmed me in my belief in the value of the fruit treatment, and in the strawberry treatment in particular. The plan I follow is to give one or two strawberries with each feed of milk, and, if found to agree, to increase the number gradually until 2 to 3 lb. are taken daily. Preserved fruits, particularly peaches and pears, make suitable substitutes if strawberries or bananas are not obtainable. The bael fruit or Bengal quince (*Ægle marmelos*), introduced by Fayrer in the treatment of this disease, seems to exert a very beneficial effect in the countries (Ceylon and India) where it can be procured in a fresh state. Extracts, such as those sold in this country, appear to be inert. The ripe fruit should be scraped out of the hard exterior shell, and eaten raw with sugar and cream. Two or three fruit, depending on their size, may be given every day.

Treatment with meat juice and underdone meat.—Occasionally symptoms persist or become aggravated under this system of treatment, and one is forced to conclude that milk does not suit the patient. In such cases raw-meat juice will often prove an efficient substitute. The juice of 4 or 5 lb. of fresh lean meat, and a little water to allay thirst, may be taken in small quantities at short intervals daily. After a time, when the stools are reduced in number and quantity, although perhaps not quite solid, scraped meat, or very much underdone meat, and by and by a little charred toast, a plain rusk or biscuit, and so forth, may be gradually added to the diet.

Meat and warm water diet.—Not infrequently, after the stools have become solid under a carefully regulated pure milk diet, it is found that any attempt to return to ordinary food, or to take anything beyond the most simple farinaceous dishes, is quickly followed by a recurrence of diarrhœa and the familiar flatulent dyspepsia. Such cases are sometimes successfully treated by a complete abandonment of milk, fruit, and farinaceous stuffs for a

time, and placing the patient on what is known as the "Salisbury cure." This is a diet consisting only of meat and warm water. Commencing with smaller quantities, in time the allowance of meat is gradually raised to about 3 lb. per diem, taken at equidistant intervals in three or four meals. The meat must be of good quality, free from fat, coarse fibre, and gristle; it may be prepared as mince, or in the form of steak or chop, not too much cooked. Warm water, amounting in all to 4 pints in the twenty-four hours, is drunk before going to bed and on rising in the morning, and also about two hours before meals —never at meals. This course must be persisted in for six weeks, when ordinary food will be gradually attempted again. I have sometimes found it useful in cases of relapsing sprue to make the patient fast systematically one day a week, feeding him on that day on milk only. Sometimes, in cases of active sprue, I have found benefit by intermitting the pure milk diet for a day or two every week, and on these days feeding the patient on minced meat and hot water only.

Nutrient enemata or suppositories.—In all grave cases of sprue nutrient enemata or suppositories should be steadily administered every four or six hours. If tolerated they are most valuable aids to nutrition. It is well, when using them, to wash out the rectum once a day with cold water.

These methods of treatment—followed by a carefully selected and increasing mixed diet, combined with warmth and rest—are in my experience the most successful methods of treating sprue; should they fail, the chances of recovery are poor indeed. Nevertheless, I have seen cases in which, after failure of the most carefully carried-out milk or meat diets, a mixed diet proved successful for a time. In such mixed diets, in fact in all diets in sprue, *restriction in the amount* is as important, perhaps, as the quality of the food consumed. Food should never be given unless the patient is hungry. It is a great mistake to try to make these patients fat rapidly, or to stimulate the desire for food by encouraging active exercise.

The bowel is not in a condition to deal with large meals.

When to send the patient to Europe. — When sprue develops in the tropics, if feasible the patient should be sent to Europe as soon as possible. It is a mistake, however, to ship an invalid with his disease active on him, or if his end is manifestly not very far off. Diarrhœa should not be active when the patient is put on board ship. In every case provision, such as a cow or an abundant supply of sterilized milk, should be made for carrying on treatment during the voyage.

The clothing and general management.—Sprue patients returning to Europe ought to be especially careful in their clothing, and they ought to get out their warm clothes before the ship leaves the tropics. If their return is during the winter, they should arrange to remain in the South of Europe till at least late spring. Next to an unsuitable dietary, perhaps cold is the most prejudicial influence to which a sprue case can be exposed. A sprue patient ought never to feel cold; he ought always to wear thick flannels, thick stockings, and, when up and about, thick boots. In winter a chamois-leather waistcoat, provided with sleeves, is of great service. His rooms ought to be warm. He ought to eat very sparingly. He ought never to be fatigued; he ought to go to bed early and rise late; in fact, he ought to do everything in his power to avoid irritating the bowel, to guard against chill, physiological depression, and the necessity for copious eating. During the summer England is suitable enough as a residence; but during the cold winter and spring months some milder, drier, and more sunny climate must be sought out.

Drugs in sprue.—Experience soon teaches one to distrust medicines in sprue. Occasionally a gentle aperient or, if diarrhœa is watery and excessive, a few drops of laudanum are of service; but active drugging of all sorts is, as a rule, in the highest degree prejudicial. If the mouth is very painful, cocaine—5 gr. to the ounce—brushed on before eating will deaden

sensibility and, for a time at all events, relieve suffering. Constipation must be carefully avoided, and a simple enema used if necessary.

I think it right to state that two methods of drug treatment seem, in some cases, to have been followed by good results. One, advocated by Dr. Begg, late of Hankow, consists in the administration of repeated doses of yellow santonin. He recommends one or two doses of castor oil to commence with, and, thereafter, 5 gr. of santonin in a teaspoonful of olive oil once or twice a day for a week, diet being at the same time attended to. The other method has gained for an irregular practitioner in Shanghai some reputation. It consists in the repeated administration of purgatives, alternately with or before the exhibition of large quantities—two teaspoonfuls at a time—of some form of carbonate of lime, believed to be powdered cuttlefish bone or powdered crabs' eyes. I have tried the santonin treatment without benefit to patients. I have also used cuttlefish bone; in one case with the result of permanently stopping the diarrhœa but not of arresting the progress of the disease. In this case, although diarrhœa was most effectively checked, yet massive solid stools continued to pass. After a few weeks the patient died from asthenia, notwithstanding a liberal diet, which apparently was digested but not absorbed.

Of late I have been in the habit of using intramuscular injections of very minute doses of arseniate of iron. In some instances the benefit from these injections has been prompt and marked. I would recommend their employment in every case of sprue in which anæmia is pronounced.

The sprue patient, if possible, ought not to return to the tropics. If compelled by circumstances to do so, he must exercise the utmost care with regard to his health, and avoid exposure, fatigue, cold bath, alcohol, and all excesses; take a minimum of, or avoid altogether, red meat; purge gently, and go on absolute milk diet on the slightest sign of relapse.

in flannel pyjamas, and with a thin blanket drawn over his abdomen; during the day he wears a woollen undervest and very likely serge or thin tweed clothes. He does not sit down in damp clothes, and he has a great respect for a shower of rain. Besides chill, there are other causes which may convert the hyperæmia into congestion or inflammation; a blow may operate in the same way, so may a surfeit of eating or drinking, so may exposure to the sun, so may an attack of malarial fever or of dysentery.

Treatment.—Nature sometimes effects a cure in these cases of hepatic congestion by establishing a smart diarrhœa. In the treatment of such cases we cannot do better than to imitate Nature, and even to supplement her efforts. A few doses of the sulphates, in the shape of some kind of bitter water or of Carlsbad salts, generally give prompt relief. But if the subject of such attacks does not profit by experience and mend his ways, very likely his liver, in time, will become chronically hyperæmic and extremely liable to intercurrent attacks of congestion of a character more or less acute. The subjects of this type of "liver" ought to be most careful in their habits. They must not lie abed too long; they must not take cold baths; they must not take cold drinks, nor expose themselves to cold in any form; they must clothe warmly; and they must eschew alcohol in every shape. Animal food they must partake of but sparingly; and they should give the preference to fowl and fish over beef and mutton. Fruit and farinaceous food may be more freely partaken of, but over-eating in every form must be avoided. Exercise should be taken at least twice a day; and, at least once in twenty-four hours, the exercise should be of such a character as to provoke perspiration. A gallop on horseback, a smart game of tennis or rackets, are excellent hepatic stimulants. Occasionally, once a week or not so often, particularly when a sense of fullness or aching in the right side seems to indicate that all is not right with the liver, a dose of Carlsbad salts or bitter water, preceded perhaps by a few grains of calomel, may avert more serious trouble.

When hyperæmia becomes chronic, when the patient is continually suffering with "liver," he should leave the tropics for a time. Nothing relieves these cases of chronic congestion so quickly or so effectively as a visit to Carlsbad or to Harrogate, and a thorough course of the waters there and of the dietetic restrictions imposed in the Carlsbad cure. This should be followed up by country life in England and the active pursuit of country sports; the usual precautions in the shape of warm clothing, avoidance of cold baths, chills, alcohol, and high living being scrupulously observed and a weekly saline purge taken.

A serviceable imitation of the natural Carlsbad water may be made by dissolving 53 gr. of the powdered salt in a pint of boiling water.* This may be divided into three equal portions, which are to be sipped as hot as possible, at intervals of twenty minutes, on an empty stomach, the first thing in the morning. While taking the solution, gentle exercise, as moving about the room, should be indulged in. Breakfast must not be taken till an hour after the last dose. If the bowels are not gently acted on, an increased quantity of the salts should be taken. During the course, which should be persevered in for three weeks, the diet must be carefully regulated; butter, fat, nuts, fruits, pastry, preserves, tinned foods, cheese, salads, wines, spirits, and beer are to be avoided. Too much meat must not be taken; a small meat meal once a day must suffice. The quantity of food, too, should be restricted, and clothing, exercise, and bathing be carefully attended to. Much excellent advice on the subject of the Carlsbad treatment will be found in Surgeon-Major Young's book, "The Carlsbad Treatment for Tropical Ailments."

During severe attacks of acute congestion, or of severe hepatitis attended with fever and much local distress, the patient must be kept in bed and placed on a very low diet of thin broths, barley-water or rice-water, or milk and water. He should be purged

* A good substitute for Carlsbad salts consists of sod. sulph. 2 parts, sod. bicarb. 1 part, sod. chlorid. 1 part.

[illegible]

[illegible]

[illegible] hepatitis [illegible] dysentery [illegible] measures [illegible]

[illegible] dysentery [illegible] point. [illegible] deny that [illegible] unassociated [illegible] will be discussed [illegible] Malarial hepatitis has [illegible]

CHAPTER XXXIV

ABSCESS OF THE LIVER

Definition.—A form of suppuration in the liver, occurring especially in warm climates, principally in male Europeans and in association with amœbic dysentery.

Geographical distribution.—Abscess of the liver, of the type known as tropical abscess, is, for the most part, a disease of warm climates. Usually a sequel, or, it may be, a concomitant of amœbic dysentery, it is rare or altogether absent in countries where this type of dysentery is also rare or absent. Its geographical distribution, therefore, is in the main regulated by that of amœbic dysentery. It has to be noted, however, that liver abscess is not a sequel or concomitant of the dysentery of all countries and at all times. Thus it is rare as an indigenous disease in temperate climates, even in those temperate climates in which dysentery is at times common enough. Again, in tropical climates the dysentery and liver abscess curves do not everywhere and at all times maintain a constant and definite relation to each other; for, even in hot countries, the dysentery of some places is more apt to be followed by liver abscess than is the dysentery of other places; and, even as regards dysentery in the same place, some epidemics are more apt to be associated with liver abscess than are others. Manifestly this apparent anomaly depends on the type of dysentery. On the whole, it may be laid down as a fairly general law that in the tropics and sub-tropics the liver abscess curve follows, in the main, the dysentery curve; and that the geographical range of liver abscess in these climates is the same as that of dysentery.

In Great Britain the liver abscesses met with occur most frequently in individuals who manifestly

had contracted the disease in the tropics. As a disease of indigenous origin, notwithstanding the considerable amount of dysentery in lunatic asylums and similar large public institutions in Great Britain, it is distinctly rare, though not so uncommon as is usually supposed. Of course this remark does not apply to those suppurations which are connected with ordinary pyæmia, with gall-stones, hydatids, pylephlebitis, and the like; it applies only to dysenteric and, possibly, if there be such a disease, to idiopathic abscess. In northern and central Europe it is much the same in this respect as in Britain. The disease is more frequent in southern Europe—in Italy, Greece, the Balkan peninsula, and south Russia; it is said to be particularly common in Roumania. In eastern Asia, even outside the tropical belt, it is far from rare: thus, it is not uncommon in Japan, and it is a very notable feature of the morbidity of Shanghai and the coast of south China. In north and tropical Africa it is common enough; indeed, some of the best modern studies of the disease have been made in Egypt and in the Algerian province of Oran. In the western hemisphere there is a corresponding distribution; fairly common in the tropics, it becomes progressively rarer as we proceed north and south. It is apparently less common in the West Indies than in India and the East generally. In the southern hemisphere, although the Cape and Transvaal and the cooler parts of Australia seem to enjoy a practical immunity, the European in the Northern Territory of Australia and in the neighbouring island of New Caledonia is subject to this disease.

The apparent caprice in the geographical distribution of liver abscess is probably, in great part, explained by what has already been stated with regard to the distribution of amœbic dysentery, and to the effects of high atmospheric temperature and tropical habits on the European liver, together with the circumstance, as will be mentioned in the sequel, that the amœba is an important, if not a principal, element in the production of tropical liver abscess.

Evidence tends to show that liver abscess is the sequel or *associate of amœbic dysentery*—a disease practically confined to warm climates; not of bacillary dysentery, the only form of dysentery occurring in temperate and some warm climates.

Etiology. *Relation to dysentery.*—There can be no question as to the existence of an intimate relationship between dysentery and liver abscess. Numerous and well-authenticated statistics, as well as everyday experience, attest this. In 3,680 dysentery autopsies made in various tropical countries, and collated by Woodward, 779 (21 per cent.) revealed abscesses of the liver. To quote recent Indian experience: According to the Annual Report of the Sanitary Commissioner with the Government of India for 1894, out of 465 European soldiers who died from dysentery in India during the period 1888–94, 161 (35 per cent.) had, in addition to dysenteric lesions, abscess of the liver. Conversely, in Egypt, Kartulis, in an experience of over 500 cases of liver abscess, elicited a history of dysentery in from 55 to 60 per cent.; Zancarol, also in Egypt, in 444 cases, elicited a similar history in 59 per cent.; and Edwards and Waterman, in 699 collated cases, elicited a like history in 72·1 per cent. During the period 1870–95, of 45 cases of liver abscess treated at the Seamen's Hospital, Greenwich, and collated by Mr. Johnson Smith, post-mortem evidence or a distinct history of dysentery was obtained in 38 (84·4 per cent.).

These figures are conclusive as to the existence of an intimate relationship between dysentery and liver abscess. There is good reason, however, for believing that, while they represent the truth, they do not represent the whole truth, and that the association is even more frequent than they indicate. As has been pointed out by Macleod and others, the occurrence of antecedent dysentery in cases of liver abscess is very often overlooked; for, without a post-mortem examination, it may be impossible to pronounce definitely on this point in every instance. It is also well known that extensive dysenteric ulceration may be present and yet give rise to no active

subjective symptoms whatever. Moreover, many patients suffering from liver abscess forget, or fail to mention, the occurrence of a previous dysenteric attack, or may mislead the physician by describing such an attack as "diarrhœa." Further, at post-mortem examinations, dysenteric lesions of a superficial and apparently trifling character are often either not sought for, or are overlooked, or have disappeared. Consequently, although the evidence of antecedent dysentery may not be forthcoming in a proportion of cases of liver abscess, it must not be concluded that in these cases there has been no dysentery.

In a masterly paper Macleod, after a very careful and critical analysis of certain figures bearing on this subject, concludes that dysentery is a factor in nearly every case of tropical liver abscess. In 40 cases of the disease observed in Shanghai he had positive evidence of dysentery in all except one; and even in this case, as recovery ensued, there was no certainty that dysenteric lesions had not been present. Perhaps Macleod's conclusions are somewhat too sweeping; I confess, however, that they are, in the main, in harmony with my own experience. Doubtless they apply to liver abscess as met with in Shanghai and, probably, in many other places. It is just possible, however, that what holds good for one place may not hold good for all places, and that Bombay, for example, may differ in this respect from Shanghai. In the Sanitary Commissioner's Report, above referred to, it is stated that in 2 (3 per cent.) instances only, out of 74 cases of liver abscess occurring in the Bombay Presidency in the period 1888–94, were there dysenteric associations. It is difficult to believe that, did it always exist, so important and evident a circumstance as dysentery had been overlooked in 72 out of 74 cases. It is equally difficult to believe that the liver abscess of Bombay is associated with dysentery in only 3 per cent. of cases, whilst, according to the same authority, in the whole of India it is certainly so associated in at least 30 per cent. of the total cases. Manifestly, the statistical aspect of this important question requires re-study in

the light of more careful clinical and post-mortem observation.

Another important point yet to be definitely settled is the exact relationship in point of time of the dysentery to the liver abscess. In the great majority of cases the dysentery antedates the abscess. But many clinicians have held that in some instances the relationship is reversed; that in others the two diseases are from the commencement concurrent; whilst in others, again, hepatitis, presumably of a kind which may eventuate in abscess, alternates with active dysenteric symptoms. If the abscess antedate the dysentery, then the dysentery cannot be the cause of the abscess. On these grounds some pathologists have regarded liver abscess and dysentery as but different expressions of one morbid condition; reacting to some extent on each other, but not directly related the one to the other as cause and effect. Here, again, the latency as regards symptoms of some dysenteries has to be discounted in attempting to settle the question on clinical grounds only. All these discrepancies and differences of opinion have to be re-studied in the light of the acknowledged relationship of the amœba to dysentery and to liver abscess.

Race, sex, and climate.—Besides its relationship to dysentery, there are several well-ascertained facts to be reckoned with before we can arrive at sound views on the subject of the etiology of liver abscess.

1. Though common in Europeans in the tropics, liver abscess is rare among the natives. Thus, in the native army of India the proportion of deaths from liver abscess to the total mortality in 1894 was only 0·6 per cent., whereas in the European army it was 7·4 per cent. Man for man, the relative liability of the European soldier and the native soldier was as 95·2 to 4·8.

2. This disproportion is in spite of the fact that the native is more liable to dysentery than the European. Thus, in 1894, in the Indian army the admission rate among the native troops for dysentery was 43·8 per thousand, whereas in the European troops it was only 28·6; and in every hundred deaths

in the native army 4·7 were from dysentery, against only 3·8 in the European army.*

3. European women in the tropics, though quite as subject to dysentery as European men, rarely suffer from liver abscess; children hardly ever.

4. The rarity of liver abscess in temperate climates.

Predisposing conditions.—The foregoing considerations seem to indicate that for the production of liver abscess at least two things are necessary—a predisposing cause and an exciting cause. Dysentery is certainly not always and alone both the exciting and the predisposing cause. Were this so, native soldiers and European women and children in India would suffer as frequently from liver abscess as do European males there. Some additional factor evidently complicates the problem.

As liver abscess is developed principally in tropical climates and in European visitors there, and much more rarely in the native, it would seem that tropical conditions in those unaccustomed to them are in some way bound up with this predisposing element; and as liver abscess is rare in European women and children, it would seem that these conditions are in some way specially operative on European men. We have grounds, therefore, for concluding that, in addition to general tropical conditions, it must be the greater amount of exposure to which men, as compared with women and children, are subjected in the course of their business and amusements; or some other condition, especially that one which is relatively more common in men than in women and children, and which is a universally recognized cause of hepatic disturbance—over-indulgence in stimulating food and alcoholic drinks — that constitutes this predisposing

* Dr. Rees informs me that liver abscess is more common among the natives of Nigeria than these figures seem to show it to be among the natives of India. Among the negroes, he says, the mortality in dysentery is much higher than among Europeans resident in Nigeria. Of those negroes attacked with dysentery who lived long enough, many subsequently developed liver abscess. Liver abscess is common in Indian immigrants in Fiji, in whom also amœbic dysentery is common, whereas in the native Fijian both amœbic dysentery and liver abscess are rare (Bahr).

cause. Intemperate habits and exposure, doubtless, lead to a special liability in men to a hyperæmia and congestion of the liver tissue by which its resistance to pathological influences is impaired. In these circumstances, pathological influences which in the healthier condition of the organ—such as we assume to exist more generally in natives and in European women and children—would have been successfully overcome, gain the upper hand and lead to suppurative disintegration of the organ. In support of this view we have the statement of Waring that 65 per cent. of liver abscesses observed by him were in alcoholics; and it is also said that when the native takes to European habits in the matter of eating and, especially, of drinking, his liability to liver abscess is greatly and proportionately increased.

I conclude, therefore, that in the vast majority of instances the exciting cause of liver abscess is dysentery; the predisposing cause hyperæmic, congestive, or degenerative conditions incidental to tropical life, supplemented by such things as exposure and unphysiological habits in eating and drinking.

Supplementary causes.—It is conceivable that in a highly predisposed liver exciting causes other than dysentery, such as a blow or sudden aggravation of chronic congestion by chill or excess, may suffice at times to determine suppuration. Liver abscess is most prone to develop at the commencement of the cold season. Further, one can conceive that in a hyperæmic liver struggling to resist dysenteric suppurative influences some third condition, such as the blow, chill, or surfeit referred to, may contribute to or determine the formation of abscess which, in its absence, might have been averted.

Briefly stated, the causes of liver abscess are, first, predisposing—hyperæmic and degenerative conditions of the liver; second, exciting—dysentery, or dysentery combined with chill, dietetic excess, or traumatism.

Influence of age and length of residence.—Liver abscess may occur at any age after childhood, but is most common between 20 and 40. It is most prone to show itself during the earlier years of residence in

the tropics (40 per cent. in the first three years), although the older resident is by no means exempt.

Influence of malaria.—Malaria, by causing frequent attacks of hepatic congestion and by lowering the general vitality, may have some predisposing influence; but, as already pointed out, malarial hepatitis is essentially of a plastic and not of a suppurative nature. It is a common mistake to suppose that malaria causes the suppurative liver disease of the tropics; the two concur geographically to a certain extent, but are in no way etiologically identical.

Morbid anatomy.—It may be inferred from the symptoms that in the early stages of suppurative hepatitis there is general congestion and enlargement of the liver; in some instances this condition may be more or less confined to one lobe or even part of a lobe. Later, as we know more especially from observations in cases that have died from the attendant dysentery, one or more greyish, ill-defined, anæmic, circular patches, ½–1 in. or thereabouts in diameter, in which the lobular structure of the gland cannot be made out, are formed. These grey spots are very evident on section of the organ. A drop or two of a reddish, gummy pus may be expressed from the necrotic patches—for such they are. Still later, the centres of the patches liquefy, and distinct but ragged abscess cavities are formed. An abscess thus commenced extends partly by molecular breaking down; partly by more massive necrosis of portions of its wall; partly by the formation of additional foci of softening in the neighbourhood and subsequent breaking down of the intervening septa. The walls of such an abscess have a ragged and rotten appearance. Spherical on the whole, there may be one or more diverticula extending from the main cavity; or contiguous abscesses may break into each other and communicate by a sinus. Occasionally a thickened blood-vessel is met with stretching across the cavity. Though the pus and detritus lying on the abscess wall are viscid and adhesive, there is no notable exudation of lymph either lining the cavity or in the still living liver tissue beyond. There is

a peripheral zone of hyperæmia ; beyond this zone the gland may appear normal or simply congested.

Number, size, and situation of abscesses.—Liver abscess may be single or multiple. If multiple, there may be two, three, or many abscesses. Zancarol's statistics, applying to 562 cases, give the proportion of single to multiple abscess cases as three of the former to two of the latter.

When single the abscess sometimes attains a great size. Frequently it is as large as a coco-nut or even larger; it has happened that the entire liver, with the exception of a narrow zone of hepatic tissue, has been converted into a huge abscess sac. When multiple the individual abscesses are generally smaller, ranging in size from a filbert to an orange.

As might be expected from considerations of the relative size of the parts, single abscess is much more common in the right than in the left and smaller lobes. What might be termed the seat of election is the upper part of the right lobe. Roux gives the proportions in 639 cases as 70·85 per cent. right lobe, 3 per cent. left lobe, and 0·3 per cent. lobus Spigelii.

Adhesions to surrounding organs are frequently, though not invariably, formed as the abscess approaches the surface of the liver. In this way the danger of intraperitoneal extravasation is usually averted.

Pulmonary inflammation and abscess from escape of liver pus into the lungs are sometimes discovered postmortem. Generally the pulmonary abscess communicates with the mother abscess in the liver by a small opening in the diaphragm, the pleural sac being shut off by adhesions.

Liver pus.—The naked-eye appearance of liver pus is peculiar. When newly evacuated it is usually chocolate-coloured and streaked with, or mixed with, larger or smaller clots or streaks of blood, and here and there with streaks of a clear mucoid or yellowish material. It is so thick and viscid that it will hardly soak into the dressings; it lies on the surface of the gauze like treacle on bread,

spreading out between the skin and the dressing, and finding its way past the edge of the latter rather than penetrating it. When quite fresh, here and there little islands of what may be described as laudable pus may be made out in the brown mass. Sometimes it contains considerable pieces of necrotic tissue. Occasionally, from admixture of bile, the abscess contents are green-tinged. Liver purulage has always a peculiar mawkish odour; it is rarely offensive unless the abscess lie near the colon, in which case it may have a fæcal odour. Under the microscope many blood corpuscles are discoverable, besides much broken-down liver tissue, large granular pigmented spherical cells, leucocytes, débris, oil globules, hæmatoidin crystals, and, occasionally, Charcot-Leyden crystals and amœbæ; rarely the ordinary pyogenic bacteria.

Amœbæ and pyogenic organisms.—According to my experience of tropical abscess of the liver seen in England, amœbæ can be detected in considerably over half the cases. This agrees with Kartulis's experience in Egypt, and that of others elsewhere. Rogers concludes from a careful examination of scrapings from the walls of a large number of liver abscesses in Calcutta that the amœba is always present. I have observed in a good many instances in which I have failed to detect the amœba in the aspirated liver pus, or in the pus which escaped at the time of operation, that the parasite appeared, often in great profusion, four or five days later in the discharge from the drainage-tube. I have seen them in these circumstances in strings of eight or ten; the string-like arrangement suggesting that they had developed in some tube, such as a blood- or bile-vessel. The amœbæ may persist in the discharge until the abscess has healed. It is justifiable to infer from the absence of amœbæ from the pus constituting what might be called the body of the abscess, and their appearance in the pus coming from the walls of the abscess a few days later, that the habitat of the parasite is not so much the pus occupying the general abscess cavity as that immediately in contact with the wall and the breaking-down tissues themselves. This is an

inference entirely in harmony with Councilman and Lafleur's demonstration, confirmed by Marshall, of the parasite in the still living tissues around the abscess. In my experience the presence of the amœba does not affect prognosis unfavourably. Lafleur says it does : I cannot agree with him. In common with many other observers I have often seen amœbic liver abscess recover completely and rapidly after operation.

Other protozoa have been found in liver pus. Thus, both Grimm and Berndt have found numerous active flagella-like organisms therein. Some time ago, in the expectorated pus from a liver abscess discharging through the right lung, I found a ciliated infusorian resembling *Balantidium coli.*

In the pus of a large proportion of liver abscesses both microscopical examination and culture may fail to detect the usual pyogenic micro-organisms. To harmonize this well-established fact with modern views on the cause and nature of the suppurative process, it has been suggested that, though in these sterile abscesses micro-organisms had originally been present, they had subsequently died out. This view receives a measure of support from the fact that in a proportion of instances there is no difficulty in demonstrating in the pus the ordinary pyogenic bacteria and, sometimes, the *Bacterium coli commune.* It by no means follows from this circumstance, however, that bacteria are a necessary factor in the production of all liver abscesses.

Encystment.—In rare instances the pus of liver abscess, instead of possessing the chocolate colour and viscid consistency described above, is yellow and creamy. This is particularly the case when the abscess becomes encysted—an occasional event. The walls of these encysted abscesses are thick, smooth, resistant, and fibrous. In time their contents become cheesy, and ultimately cretified ; in the latter event the cyst shrivels up and contracts to a small size.

Pathology.—The pathology of liver abscess has been a fruitful source of speculation and controversy. Much confusion has crept into the question from

attempts to separate, etiologically and pathologically, multiple from single liver abscess. The former is often called "pyæmic abscess" or "dysenteric abscess," and has been set down as being the peculiar sequel of dysentery; the latter has been called and considered the "tropical abscess" *par excellence*, and regarded as idiopathic and entirely unconnected with dysentery.

As already pointed out, a careful examination of cases and statistics shows that both forms of abscess, single and multiple alike, are, in the vast majority of instances, clearly associated with dysentery. In their respective clinical histories, in their symptoms, in the characters of their walls and contents, in the frequent presence of amœbæ, single and multiple abscesses are practically identical. The only difference between them is a numerical one—a circumstance quite inadequate to base a doctrine of specific distinction upon. In sections of amœbic ulcer of the colon amœbæ may often be demonstrated lying between the muscular fibres, and even in the veins of the peritoneal coat, indicating the route by which they reach the portal circulation.

The view which I incline to hold on this subject has already been partly given in the section on etiology. There are two factors which are principally concerned in the production of liver abscess: (1) the predisposing—weakening of the resistive faculty of the liver by chronic congestion or tissue degeneration, and, perhaps, other subtle changes brought about by a combination of climatic, dietetic, and other tropical conditions; (2) the exciting—some micro-organism, streptococcus, staphylococcus, *Bacterium coli commune*, or other parasite, especially the amœba, which, coming from the ulcerated dysenteric colon, or by way of the portal circulation (Marshall has demonstrated amœbæ in a thrombus in a branch of the portal vein), gains access to the liver and proliferates in the weakened tissues. In at least 90 per cent. of cases the micro-organism is associated with or derived from dysenteric processes in the colon. Whether the resulting abscess be

single or multiple is more or less a matter of accident. If the weakened liver is efficiently inoculated at one point only, there is only one abscess; if at many points, then there is multiple abscess. This is virtually, in a sense, Budd's theory expressed in modern terms.

An apparently weighty objection to this view is sometimes urged. Why, it is asked, if liver abscess be the result of septic absorption from a dysenteric ulcer, is it not a common sequel of typhoidal or of tuberculous ulceration in the tropics? Macleod has met this objection very ingeniously and, I believe, to a certain extent, correctly. He points to the fact that typhoidal and tuberculous ulcerations are surface lesions unattended with abscess formation in the wall of the bowel. In their case there is free escape of the products and germs of ulceration; whereas in dysenteric lesions, in addition to the superficial ulceration, there is often what is really abscess formation with burrowing and retention of pus below the mucous membrane, and therefore great liability to entrance of micro-organisms into the radicles of the portal vein. Liver abscess, therefore, according to this view, is a pyæmic process. Often, however, it must be confessed, the dysentery preceding liver abscess appears, judging from the symptoms, to be of the catarrhal rather than of a more severe type; but even in this case it may be that the amœba penetrates the portal radicle without producing ulceration.

To what extent the amœba is concerned in the production of tropical liver abscess it is as yet impossible to state. If the frequency of its presence is any indication it must be the usual if not the only cause. If we watch the movements of this animal on the warm stage; and if we reflect that it lives and wanders about in the same very active way among the structures forming the walls of the liver abscess, and even in what are comparatively sound tissues, preceding, as it were, the suppuration, or rather, the necrotic process; and consider that it lives at the expense of these tissues, it is hard to resist the conclusion that the amœba

must operate as a disintegrating and irritating agency. Kartulis suggests that it may act merely as a carrier of pus-forming bacteria. Others maintain that it is a harmless epiphenomenon, incapable in any way of inducing pus formation. As yet experimental pathology has not given a decisive answer to this, one of the most important questions in tropical pathology, though later experiments are very suggestive; amœbic dysentery and liver abcesses have been produced in cats by numerous investigators by rectal injection both of amœbic dysenteric stools and sterile liver pus containing amœbæ; these organisms have been demonstrated in the liver pus and intestinal walls of these animals after death. Furthermore, Harris and Gauducheau have been able to produce dysentery and liver abscesses in dogs by similar injections of amœbic pus, the latter by the intravenous route.

Calmette, in view of the frequency with which he and others have found liver abscess to be sterile, suggests that the exciting agency is of a chemical nature, some irritating liquefying body derived from the decomposition processes going on upon the surface of the dysenteric ulcer.

Symptoms.—There is great variety in the grouping of symptoms in liver abscess. The following is a common history: The patient, after residing for some time in the tropics, enjoying good general health and living freely, was attacked by dysentery. In due course he appeared to recover, and resumed work. Several weeks or months elapsed when, after a wetting, or some such incident, he began to feel out of sorts, to suffer from headache, foul tongue, want of appetite, irregularity of the bowels, disturbed nights, excessive and unaccountable languor, irritability of temper, and depression of spirits. About the same time he began to be conscious of a sense of weight and fullness in the right hypochondrium. Later he became feverish, particularly towards evening, the oncoming of the febrile distress being sometimes preceded by a sense of chilliness. At times he had sharp stabbing pain in the right side in the region of the liver, perhaps a dry cough and, possibly, a gnawing, uncomfortable

sensation or pain in the right shoulder. His friends observed that his face had become muddy and haggard. He was uneasy if he lay on his left side. The quotidian rise of temperature now became a regular feature, the thermometer every evening touching 102° F.—sometimes more, sometimes less—and sinking to near normal by morning. He now began to perspire profusely at night, and even during the day when he chanced to fall asleep. He had to change his sleeping clothes once or even twice every night on account of the drenching sweats.

On examination it is found that the patient is somewhat emaciated; his complexion thick and muddy; his pulse 80 to 100; his tongue furred and yellowish; the palms of his hands and soles of his feet cold and clammy. As he lies on his back it is obvious, on inspection, that the epigastrium is too full for one so emaciated; and it is seen that the breathing is shallow and mainly thoracic. The right rectus muscle is rigid. Considerable discomfort, if not pain, is elicited by attempts at palpation and percussion over the right hypochondrium. The liver dullness extends an inch too high, and an inch or more beyond the costal border in the nipple line; posteriorly it rises to about the eighth rib in the line of the angle of the scapula. It is further observed that the line of dullness is arched along its upper border; and that it is altered by changes of position, the upper line descending when the patient lies on his left side or stands up; in the latter position the lower margin descends markedly in the epigastrium. On deep inspiration, percussion below the right costal border gives rise to much uneasiness or even to acute pain. Very likely one or two tender spots can be discovered on firm pressure being made with the finger-tips in some of the lower right intercostal spaces, or below the right costal margin. The spleen is not usually enlarged. Auscultation may detect pleuritic friction somewhere over the base of the right lung, or peritoneal friction over the liver itself. The urine, free from albumin, is scanty, high-coloured, and deposits urates. The blood shows well-marked polymorphonuclear leucocytosis.

As the case progresses emaciation increases; hectic with drenching nocturnal sweats continues; the liver dullness and pain may further increase; or the general enlargement may somewhat subside, and percussion may reveal a pronounced local bulging, upwards or downwards. If the abscess which has now formed is not relieved by operation, after months of illness the patient may die worn out; or the abscess, which has attained enormous dimensions, may burst into the right lung or pleura, or elsewhere, and be discharged, and either recovery, or death from continued hectic and exhaustion or from some intercurrent complication, ensue.

Great variety in the urgency of symptoms.—Although the foregoing is a fairly common history in liver abscess, there are many instances in which the initial symptoms are much more urgent, and in which the disease progresses much more rapidly. In other instances subjective symptoms are almost entirely absent; or so subdued that the true nature of the case may be entirely misapprehended until the abscess bursts through the lung or bowel, or a fluctuating tumour appears in the neighbourhood of the liver; or, perhaps, not until after death, when the unsuspected abscess is discovered on the post-mortem table.

Fever.—In an acute sthenic case the initial inflammatory fever may run fairly high and persist for some time. Later, when it may be assumed that pus has formed, the fever becomes distinctly quotidian and intermittent in type, the morning temperatures being normal, or only slightly above normal, the evening rising to 101° or 102° F., or a little over or under this. Sometimes evening temperatures of 103°, rarely of 104°, are registered. In the asthenic and insidious type, at first there may be short flashes of feverishness at more considerable intervals, to be followed later by a steadier fever of a hectic type, as in the suppurative stage of the sthenic cases. In either type there may be afebrile intervals of several days' duration; and in either there may also occur, concurrently with aggravations of the local conditions, spells of continued high temperature. Occasionally,

though rarely, liver abscess may be unattended by fever of any description whatever.

Rigors.—In the classical descriptions of liver abscess the occurrence of violent rigor is generally mentioned as a notable sign of the formation of pus. Undoubtedly such a rigor does at times signalize this event; but it is by no means constant, and its absence is no guarantee that abscess has not formed. Generally the evening rise of temperature is preceded by a sense of chilliness, sometimes by a more marked rigor simulating, in the regularity of its recurrences and in its severity, the rigor of a quotidian malarial fever.

Sweating, particularly nocturnal sweating of a very profuse character, is an almost invariable accompaniment of liver abscess. The patient's clothes may be literally drenched with perspiration. Even during the day—particularly, as already mentioned, if he chance to fall asleep—the sweat may stand in beads upon the forehead and around the neck. This, like most of the other symptoms, may be temporarily absent or, in a small proportion of cases, trifling.

The *complexion* is generally muddy, cachectic and slightly icteric-looking; marked jaundice, however, is uncommon.

Wasting is generally decided and progressive.

Rheumatic-like pains and swelling of the hands and feet, such as occur in chronic septic affections, are sometimes to be noted. They usually disappear rapidly when the abscess bursts or is opened and free drainage is established.

Pain of some description is rarely absent. In a few exceptional cases there is no pain; such a patient may declare that he does not know that he has a liver.

There are several types of pain—local and sympathetic—associated with liver abscess. Complaint is almost invariably made of a sense of fullness and of a sense of weight in the region of the liver, not infrequently referred to the infrascapular region. Stabbing, stitch-like pain, increased by pressure and

especially by deep inspiration, by coughing and all sudden jarring movements, is very common, and probably indicates perihepatitis from proximity of the abscess to the surface of the organ. Percussion, or firm palpation, especially if practised during deep inspiration and below the ribs in front, generally causes smart pain and decided shrinking, the rectus muscle starting up as if to protect the subjacent inflamed parts. Pain on swallowing, at the moment the bolus of food traverses the lower end of the œsophagus, was mentioned to me by a medical man, himself the subject of hepatic abscess, as being a marked symptom in his own case. Pain on firm pressure with the finger-tips in an intercostal space, and over a limited area, is a common and valuable localizing sign. Among the sympathetic pains may be mentioned shooting pains radiating over the chest and down the right flank and hypochondrium.

Pain in the right shoulder.—This symptom is present in about one-sixth of the cases. It may be persistent, or it may intermit; it may radiate to the side of the neck, or to the region of the scapula, or down the arm; or it may be limited to the shoulder-tip and clavicular region. In some instances it is of a dull, gnawing, aching character; in others it is more acute; and in some it may be represented by a burning sensation, as if the surface of the skin had been flayed by a blister. This symptom is a reflex transmitted from the hepatic terminals of the phrenic through the fourth cervical to the branches of the cervical and brachial plexuses.

Cough of a dry, hacking character, doubtless also a reflex from irritation of the diaphragm, or from an inflamed condition of lung or pleura over the seat of abscess, is not uncommon. When the abscess discharges through the lung, cough is sometimes very severe and may cause vomiting.

Respiration is generally shallow and proportionately rapid. This is partly symptomatic of the attendant fever; oftener it is owing to the fact that fuller inspiration is attended with stitch. Sometimes the breathing is entirely thoracic, the lower part of

the chest seeming to be fixed—especially the right side—and the diaphragm almost motionless.

The *decubitus* is usually dorsal or right dorsal, the body being somewhat bent towards the right side and the right leg perhaps slightly drawn up. When the patient stands, a stoop to the right may be noticeable. Lying on the left side generally causes pain from dragging on adhesions, or discomfort from the pressure of the enlarged liver on the heart and stomach. Occasionally the decubitus is indifferent, or even on the left side.

The *digestive organs* are usually disturbed and the tongue is coated. Vomiting may occur from time to time, arising either from pressure on the stomach by the swollen liver or as an expression of gastric catarrh; appetite, as a rule, is poor; flatulence may be troublesome; the bowels are confined or irregular, or there may be diarrhœa or dysentery. In the case of concurrent dysentery, it may be noted sometimes that the hepatic and dysenteric symptoms alternate in severity.

The *area of hepatic percussion dullness* is usually extended upwards and downwards, and sometimes horizontally. The extension may be general, especially in the earlier stages; later, careful outlining of the upper and lower boundaries may discover a limited and dome-like increase in one direction, most significant if upwards. The upper line of dullness is not, as a rule, horizontal, as in hydrothorax; almost invariably, on approaching the spine, it trends downwards more markedly than in hydrothorax or empyema. Variations in the extent of the dullness may take place from time to time, and sometimes very rapidly, depending not on fluctuations in the size of the liver abscess, but on the varying and relative amounts of local and general hepatic congestion. One sometimes finds even a narrow hepatic dullness in the nipple line, with a great increase in the axillary or scapular lines. In one case the lower border of the liver may be as low as the umbilicus; in another, especially in front, it may be well inside the costal margin. Diagnosis in the latter type of case is difficult, and depends

rather on the nature of the fever and on the history and general condition than on local signs.

Splenic enlargement may be present even when there is no malarial complication. This is rare, however, and in uncomplicated cases is seldom great. I have seen splenic tumour closely simulated by abscess in the left lobe of the liver.

Varicosity of the epigastric and hæmorrhoidal veins—one or both—is sometimes discoverable.

Œdema of the feet and ascites are rare in the earlier stages; but the former is very usual towards the termination of long-standing cases.

Local œdema over one or more intercostal spaces, or more extensive and involving the whole or part of the hepatic area, is sometimes apparent. When limited it is a useful locating symptom.

Local bulging, if attended with fluctuation, indicates the presence of pus near the surface and the pointing of the abscess. Usually this, when it occurs, is in the epigastrium; but pus may burrow and find its way down the flank, or among the muscles of the abdominal wall, and open perhaps at a point remote from the abscess cavity in the liver.

Friction, both pleuritic and peritoneal, is sometimes to be made out, and is not without its value as a localizing symptom.

Pneumonia, generally limited to the base of the right lung, and of a subacute and persistent character, indicates contiguity of the abscess to the diaphragm. It is especially common in those cases in which the abscess subsequently ruptures through the lung. This form of chronic pneumonia is a fruitful source of error in diagnosis.

Chronological relation of the hepatitis to the dysenteric attack.—This is most irregular and uncertain. In many cases of dysentery a concurrent hepatitis is manifest almost from the commencement of the attack; this hepatitis may not subside, but pass directly to abscess formation. Or the initial hepatitis and dysentery may both subside apparently, but the former may recur weeks, months, or even years afterwards, when, perhaps, the attack of dysen-

tery is almost forgotten. Or there may be no active hepatic symptoms with the dysentery, hepatitis supervening only when all bowel trouble has long passed away. In a few cases no dysenteric history can be elicited ; it is seldom, however, as has already been insisted on, that careful inquiry fails to bring out some story of previous bowel disturbance more or less urgent. In a few instances liver abscess of tropical origin does not declare itself until the patient has been several years resident in a temperate climate and quite outside the endemic area.

The *incidence of the symptoms* is equally variable. Some cases commence with marked sthenic fever, much local pain, great tenderness and hepatic enlargement, the signs of suppuration, as rigor, hectic, and local bulging, rapidly supervening. Others, again, commence so insidiously that the patient can hardly say when he first began to feel ill ; perhaps there may be a history of slow deterioration of the general health during a year or longer before definite hepatic symptoms show themselves. The former type seems to be the more common in the young and robust new-comer to the tropics ; the latter, in the more or less cachectic and old resident. Between these extremes there is endless variety.

Duration of the disease.—Liver abscess may run its course in three weeks. Generally it is an affair of several months. Sometimes it may run on for a year or even longer ; particularly so if it burst through the lung and drainage be imperfect, in which event the cavity may keep on bursting and refilling at intervals for almost an indefinite period. Occasionally a liver abscess becomes encysted and gives rise to no further symptoms, its existence being discovered only on the post-mortem table, the patient having died of quite another and independent disease.

Terminations. — Apart from operative interference, liver abscess may terminate in various ways. It may end in spontaneous rupture leading to death or recovery. Death may also be brought about in other ways—by the severity of the local disease ; by prolonged hectic and exhaustion ; by concurrent

dysentery; or by intercurrent disease, as pneumonia, pulmonary abscess, empyema, peritonitis. Recovery may also ensue on the abscess becoming encysted or, possibly, absorbed.

Rupture of the abscess.—Rendu, in a series of 563 instances of abscess of the liver, compiled from various sources, gives an interesting table showing the direction of rupture in 159 of the cases which opened spontaneously. This table may be summarized as follows:—

Rupture occurred into the			pericardium	in 1	case	0·13	per cent.
,,	,,	,,	pleura	31	cases	5·5	,,
,,	,,	,,	lung	59	,,	10·5	,,
,,	,,	,,	peritoneum	39	,,	6·9	,,
,,	,,	,,	colon	6	,,	1	,,
,,	,,	,,	stomach and duodenum	8	,,	1·4	,,
,,	,,	,,	bile-ducts	4	,,	0·7	,,
,,	,,	,,	vena cava	3	,,	0·5	,,
,,	,,	,,	kidney	2	,,	0·3	,,
,,	,,	,,	lumbo-iliac region	6	,,	1	,,

From this it will be seen that about 28 per cent. of liver abscesses rupture spontaneously, most generally into the lung or pleura.

Rupture into the lung.—If rupture takes place into the lung the abscess contents may be suddenly discharged, mouthful after mouthful of pus mixed with blood welling up or being coughed up. In a few instances, in such circumstances, death has occurred suddenly from the flooding of the lungs with pus. More commonly the discharge is effected gradually, a few drachms being brought up with each cough; in the aggregate this discharge may amount perhaps to 5 or 10 oz. in the twenty-four hours. In favourable cases the daily amount expectorated gradually diminishes until all discharge ceases and the patient recovers. Frequently, however, a deceptive arrest of discharge and cessation of cough are followed by a rise of temperature, which had become normal on the occurrence of rupture. With this there may be a reappearance of the night sweats. In a few days cough and expectoration return as

before and fever once more subsides. This process of alternate emptying and refilling of the abscess cavity may recur many times before recovery finally takes place. In some cases it continues for months, and may finally wear out the patient. Abscess may form in the lung; or a sudden and fatal hæmoptysis may be brought about by ulceration opening some large pulmonary vessel. In some, expectoration never altogether ceases; if accompanied by fever this persistency indicates imperfect drainage, or, possibly, the presence of a second and unruptured abscess.

Characters of the expectorated liver pus. — The appearance of expectorated liver pus is almost pathognomonic. In colour it is chocolate brown; in consistence it is viscid and jelly-like. It may be streaked with blood; sometimes the expectoration may be almost entirely pure blood. Not infrequently these hæmorrhagic cases are regarded and treated as examples of ordinary hæmoptysis. Presumably, in the majority of instances, this blood comes from the wall of an abscess jarred and torn by the succussion of the harassing cough. Under the microscope expectorated liver pus exhibits the appearance already described (p. 570).

Rupture into the pleura leads to sudden development of evidences of pleural effusion which, unless relieved by drainage, may, in its turn, give rise to all the signs of empyema, and terminate in death, or in rupture through the lung or chest wall.

Rupture into the stomach is generally signalized by vomiting of the characteristic pus and, at all events temporarily, by cessation of local symptoms and fever.

Rupture into the bowel may cause diarrhœa, the pus, more or less altered, appearing in the stool. This is an occurrence that is frequently overlooked.

Rupture into the pericardium, or into a blood-vessel, is almost necessarily and rapidly fatal.

Rupture into the peritoneum is, of course, a serious occurrence, but, I believe, not necessarily fatal. The majority of liver abscesses, as will be presently described, do not contain the ordinary septic bacteria,

and, therefore, may not give rise to septic peritonitis. I have seen recovery after this accident, the peritoneum having been well washed out and drained.

Rupture through the skin is said to be the most favourable, though a rare termination of liver abscess.

Mortality.—Rouis (203 cases), in Algiers, observed a mortality of 80 per cent.; Castro (125 cases), in Egypt, a mortality of 72·5 per cent., or, excluding cases operated on, of 76 per cent. In the Indian army, during the period 1891–94 (prior to which abscess of the liver, in the statistical returns, is not separated from hepatitis), and, presumably, including cases operated on, the mortality was 57·7 per cent.

Causes of death.—In Rouis's 162 fatal cases the causes of death are stated as follow: Severity of the local disease, or through the associated dysentery, 125; bursting of the abscess into the peritoneal cavity, 12; into the pleura, 11; gangrene of abscess wall, 3; peritonitis, 3; pneumonia from effusion of liver pus into the lung, 3; rupture of adhesions, 2; pneumonia, 2; rupture into the pericardium, 1. Abscess in the brain is a rare but occasional cause of death; in one recorded case amœbæ were found in the pus.

Diagnosis.—Of all the grave tropical diseases none is so frequently overlooked as abscess of the liver. Acute sthenic cases are readily enough recognized; not so the insidious asthenic cases. The novice in tropical practice is some time in realizing that grave disease of so important an organ as the liver may, for a long time, be unattended with urgent symptoms, whether local, or constitutional, or both.

The most common mistakes in diagnosis are: (1) Failure to recognize the presence of disease of any description, even when an enormous abscess may occupy the liver. (2) Misinterpretation of the significance and nature of a basic pneumonia—a condition so often accompanying suppurative hepatitis. (3) Attributing the fever symptomatic of liver abscess to malaria. (4) Mistaking other diseases for abscess of the liver and vice versa—for example,

hepatitis of a non-suppurative nature, such as that attending malarial attacks; suppurative hepatitis before the formation of abscess; syphilitic disease of the liver—softening gummata which are often attended with fever of a hectic type; pylephlebitis; suppurating hydatid; gall-stone and inflammation of the gall-bladder; subphrenic abscess; abscess of the abdominal or thoracic wall; pleurisy; encysted empyema; pyelitis of the right kidney; pernicious anæmia; leucocythæmia; scurvy and similar blood diseases associated with enlargement of the liver; ulcerative endocarditis; kala-azar; Malta fever; trypanosomiasis. Any of these may be attended with fever of a hectic type, increased area of hepatic percussion dullness, and pain in or about the liver.

Many times a correct diagnosis can be arrived at only by repeated and careful study of the case in all its aspects. Golden rules in tropical practice are to think of hepatic abscess in all cases of progressive deterioration of health; and to suspect liver abscess in all obscure abdominal cases associated with evening rise of temperature, and this particularly if there be enlargement of or pain in the liver, leucocytosis, and a history of dysentery—not necessarily recent dysentery. If doubt exist, there should be no hesitation in having early recourse to the aspirator to clear up diagnosis, after employing emetine or ipecacuanha as a therapeutic test.

As bearing on prognosis, apart from the risk from sudden rupture in some untoward direction, to overlook abscess of the liver is a much graver error than to mistake some other disease for liver abscess; for the chances of recovery from operation are proportionately prejudiced by every day's delay.

Low pneumonia of the right base in a tropical patient should always be regarded with suspicion; in most instances it means abscess of the subjacent liver.

Perhaps the most common error is to regard the hectic of liver abscess as attributable to malaria. The regularity with which the daily fever recurs, the daily chilliness or even rigor coming on about the same hour, the profuse sweating, and other circum-

stances so compatible with a diagnosis of malaria, all contribute to this mistake. So common is the error that Osler says he hardly ever meets with a case of liver abscess which has not been drenched with quinine. My experience is the same. I have seen medical men make this mistake not only in their patients but in their own persons. If carefully considered, there are several circumstances which should obviate so serious an error. (1) No uncomplicated ague resists quinine in full doses. (2) In malaria, if the liver be enlarged the spleen is still more so; the reverse is the case in liver abscess. (3) The malaria parasite cannot be found in the blood in non-malarial hepatitis. (4) In liver abscess the fever is almost invariably an evening one; in malaria it most frequently comes on earlier in the day. (5) Quotidian periodicity, contrary to what is the case with tertian or quartan periodicity, is by no means pathognomonic of, or peculiar to, malaria. (6) The almost invariable history of antecedent dysentery, or, at least, of bowel complaint, in liver abscess. (7) Polymorphonuclear leucocytosis in liver abscess: relative mononuclear leucocytosis in malaria, kala-azar, and trypanosomiasis.

To mistake other forms of suppuration for liver abscess is of no great moment, because in many of the suppurative diseases just enumerated the treatment is the same as for liver abscess, and no bad result need be looked for if diagnosis is not quite accurate. A more serious error, however, is to overlook the presence of leucocythæmia, pernicious anæmia, or scurvy, and to proceed to aspirate an enlarged liver on the supposition that the symptoms arise from abscess. Fatal intraperitoneal hæmorrhage from the puncture has been known to ensue in such circumstances. If any doubt is possible on this point, a microscopical examination of the blood should be made before proceeding to explore.

A point to note in exploring is that, when the instrument enters the liver, an up-and-down pendulum-like movement will be communicated to the outer extremity of the needle, in harmony with the rising

and falling of the organ in respiration. If the needle does not exhibit this movement, its point may be in an abscess cavity, but this abscess is not in the liver.

Treatment.—Hepatitis which has not proceeded to abscess formation should be treated, especially if dysentery be present or have been antecedent, with full doses of emetine or of ipecacuanha, repeated once or twice a day for two or three days or longer, by a cautious use of the purgative sulphates, and with poultices, rest, and low diet. Rogers has recently reiterated the value of emetine and ipecacuanha in such circumstances. If there be much pain, relief may be afforded by either wet or dry cupping over the liver, or by leeches around the anus. Ammonium chloride, in 20-gr. doses three times a day, is usually prescribed.

When the occurrence of rigor, or the development of hectic, or the appearance of local bulging, or the persistency of the fever and of the local symptoms, gives ground for suspecting that abscess has formed, active medication must be suspended, a somewhat improved dietary prescribed, and measures taken without unnecessary delay to locate by means of the aspirator the position of the pus.

When he proceeds to use the aspirator, the surgeon must be prepared to open and drain the abscess if pus be discovered ; once diagnosis is established, nothing is gained by delay. By proceeding to open the abscess at once the shock of a double operation is avoided, and only one administration of the anæsthetic is required.

To facilitate aspiration, as well as the subsequent operation if such should be found to be necessary, the patient ought invariably to be placed under an anæsthetic. Unless in very special and exceptional circumstances, it is a mistake to attempt exploration without this, for the surgeon ought to proceed with deliberation and to feel himself at liberty to make as many punctures as he may think necessary. A medium- or full-sized aspirator needle should be used, as owing to the nature of the pus it may not flow through a cannula of small bore.

If there are localizing signs, such as a tender spot, a fixed pain, a localized œdema, localized pneumonic crepitus, pleuritic or peritoneal friction, these should be taken as indicating, with some probability, the seat of the abscess and the most promising spot for exploratory puncture. If none of these localizing signs is present, then, considering the fact that the majority of liver abscesses are situated in the upper and back part of the right lobe, the needle should, in the first instance, be inserted in the anterior axillary line in the 8th or 9th interspace, about 1 in. or 1½ in. from the costal margin and well below the limit of the pleura. The instrument should be carried in a direction inwards and slightly upwards and backwards and, if found necessary, to its full extent—3 to 4 in. If pus be not struck the needle must be slowly withdrawn, a good vacuum being maintained the while in case the abscess has been transfixed and the point of the needle lodged in the sound tissue beyond. No pus appearing in the aspirator, the remainder of the dull hepatic area must be systematically explored, both in front and behind, regard being had to the lung and pleura on the one hand, and to the gall-bladder, large vessels, and intestine on the other. The peculiar colour—often like dirty-brown thick blood—of liver pus must not be allowed to deceive the operator into thinking that he has failed to strike the abscess.*

At least six punctures should be made before the attempt to find pus is abandoned. Provided there is complete absence of breath sounds, of vocal fremitus and resonance over the lower part of the right lung, and pus has not been reached from lower down, then the pleura or lung may be disregarded and puncture made anywhere below the line of the nipple and angle of the scapula, or wherever the physical signs suggest.

The surgeon should be encouraged to make early use of the aspirator by the fact that its employment,

* I have seen the peculiar brownish fluid resulting from the action on blood of the carbolic lotion that had been used to sterilize the exploring syringe, mistaken for pus. To obviate so grave a mistake the exploring syringe should be washed out with boiled water before use.

even where no pus is discovered, is not infrequently followed by rapid improvement in all the symptoms. Many such cases are on record. Hepatic phlebotomy, as Harley designated the removal from the liver of a few ounces of blood by the aspirator needle, is a measure of proved value in hepatitis. With due care, risk from hæmorrhage is small; it is very small indeed in comparison with the risk of allowing an hepatic abscess to remain undiscovered and unopened.

Some surgeons, in order to obviate the small risk from hæmorrhage attending aspiration through the abdominal or chest wall, prefer to expose the surface of the liver by a short incision and then explore.

It is hardly necessary to add that strict aseptic precautions, in the way of purifying the patient's skin, the surgeon's hands, and all instruments, must be carefully observed.

Operation for abscess of the liver.—The following is the operation usually practised by English surgeons. It is substantially that described by Godlee in the *British Medical Journal* of January 11, 1890, to which the reader is referred for many valuable details and practical hints.

If pus is struck below the costal border, the aspirator needle being left *in situ* as a guide, the abdominal wall is incised down to the peritoneum. A 3-in. incision will give plenty of room. If firm adhesions be discovered, a sinus forceps is at once run along the needle, and pushed through the intervening liver tissue and into the abscess. The aspirator cannula is now removed, and the blades of the forceps are opened sufficiently, as it is being withdrawn, to make a wound in the liver big enough to admit the forefinger, which must now be inserted and moved about so as to enlarge the wound and to gain some idea as to the size and direction of the cavity of the abscess. A rubber drainage-tube, about as large as the finger, and provided with a flange, is cut to a suitable length, and carried by means of the forceps to the back of the abscess. The abscess is then allowed to empty itself. When pus no longer flows freely, a

massive antiseptic dressing is applied and firmly secured by a broad binder or many-tailed bandage.

If, after division of the abdominal wall, no reliable adhesions be discovered between this and the liver, the capsule of the latter must be securely attached to the former by a double circle of stitches. The abscess is then to be opened, as above described, with sinus forceps. After stitching, some surgeons prefer, before opening the abscess, first to stuff the wound in the abdominal wall with iodoform gauze, and to wait for a day or two for adhesions to form. Others stuff the wound with gauze without previous stitching.

Should the abscess be struck through an intercostal space, and if the latter be not deemed sufficiently wide to admit of manipulation and free drainage, a couple of inches of rib had better be excised. The diaphragm may then be stitched to the thoracic wall or, better, to the skin as well, when the abscess may be opened with forceps. To stitch the capsule of the liver to the diaphragm is a somewhat difficult proceeding; but if there are no reliable adhesions it had better be attempted, especially if the opening is to be made through a part of the liver covered by the peritoneum. If by any chance the pleura is opened during the operation, pneumothorax will result—an unfortunate but not necessarily a serious contingency. In this case the hole in the pleura must be carefully stitched in such a way that the pleural cavity is completely cut off before the diaphragm is divided and the abscess opened. Pus must not on any account be allowed to enter the pleural cavity; this, owing to the aspirating influence of inspiration, it would readily do if the smallest hole should remain patent. The young surgeon would do well to practise these operations on the dead body, and familiarize himself with the relations of the various structures involved.

Some operators of experience completely ignore the absence of peritoneal adhesions, and, even in these circumstances, open the abscess without previous stitching of peritoneal surfaces. The risk and danger of escape of pus into the peritoneal cavity,

they hold, is very small if free drainage to the outside is secured. Macleod considers that, in the circumstances, stitches will not hold in the soft and inflamed liver tissue; he also considers that, in the event of the incision having to be made in the thoracic wall, removal of part of a rib is unnecessary. On account of the liability of a rubber drainage-tube to become nipped when the emptying sac causes a want of correspondence between the wound in the abdominal or thoracic wall and that in the liver, and, also, on account of facility of introduction during the subsequent dressings, this operator uses metal drainage-tubes of suitable lengths—4 in., $3\frac{1}{4}$ in., $2\frac{1}{2}$ in., and $1\frac{3}{4}$ in.—with an oval lumen of $\frac{4}{10}$ in. by $\frac{3}{10}$ in. These tubes he introduces by means of a special guide.

The author's method.—The following easy, rapid, and efficient method of operating on abscess of the liver I have frequently practised, and can recommend. The necessary apparatus (Fig. 84), which can be made by native workmen, consists of a large trocar and cannula (*a*), 4 to 5 in. long, by $\frac{3}{8}$ in. in diameter; a steel stilette (*b*) at least 14 in. in length; two metal buttons (*c*, *d*) $\frac{1}{4}$ in. at their greatest diameter, with long ($\frac{1}{2}$ in.), hollow, roughened necks into which the ends of the stilette fit loosely; 6 in. of $\frac{1}{2}$ in. stout drainage tubing (*e*). While the ends of the drainage tubing are held and well stretched by an assistant, they are firmly lashed to the stem of the buttons, over the ends of the shorter (*d*) of which, for additional security, the tubing is also tied (*e*). Two large holes, to provide for free drainage, are then cut close to one end of the drainage-tube. The tube is then mounted on the stilette by inserting one end of the latter through one of the drainage holes and lodging it in the hollow neck of the distal button (*c*), and thereafter so stretching the rubber that the other end of the stilette can be inserted into the neck of the other button (*d*). When thus stretched the drainage-tube should be capable of passing easily through the cannula. The apparatus being so prepared and rendered thoroughly aseptic by soaking in carbolic lotion, and the direction of the abscess and its depth

from the surface having been carefully ascertained by means of the aspirator and noted, the aspirator is withdrawn and an incision, about 1 in. in length. made through the skin at the site of the puncture, The trocar and cannula are then thrust into the abscess and the trocar withdrawn. After allowing a small quantity of pus to escape, so as to relieve any tension that may be present in the abscess sac,

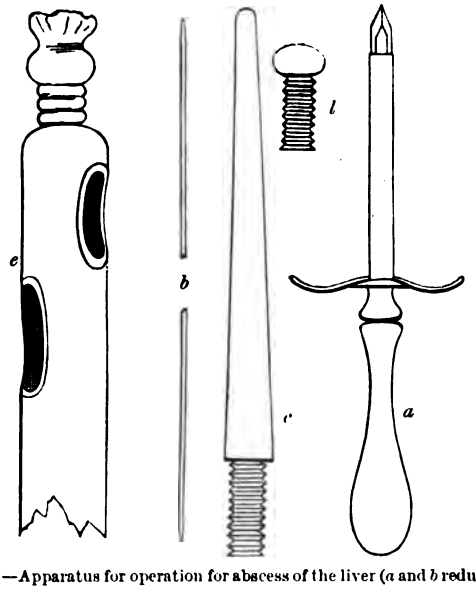


Fig. 84.—Apparatus for operation for abscess of the liver (*a* and *b* reduced).

the stretched drainage-tube, perforated end first, is slipped into the cannula and carried to the back of the abscess. Holding the stretched drainage-tube firmly, and maintaining it carefully in contact with the back of the abscess with one hand, withdraw the cannula with the other. The drainage-tube still firmly grasped, the button on the free end of the apparatus is slipped off the stilette, the end of which is made to perforate the drainage-tube close to the button. This it readily does, and the drainage-

tube is allowed slowly to resile towards the fixed end still held in contact with the back of the abscess. When the drainage-tube has completely contracted, the stilette is withdrawn. The drainage-tube is then transfixed with a safety-pin inserted close to the skin, and the superfluous tubing cut off. Pus flows freely from the tube, which now firmly plugs the wound in the abdominal wall and liver, and bridges the peritoneal cavity. When the abscess has nearly emptied itself the usual antiseptic dressing is applied. In operating through the thoracic wall, if deemed desirable, part of a rib may be excised before the trocar is introduced.

I claim for this operation that it is easily done, and that it may be undertaken by the merest tyro in surgery and in the absence of skilled assistance; that there is no risk from bleeding; that, the peritoneum being bridged across by the drainage-tube which is securely grasped by the liver tissue, there is no risk of escape of pus into the peritoneal cavity; that in a very short time lymph is effused around the tube, giving additional security when, after a time, the tube has become loose; that, if deemed necessary, a larger drainage-tube, by stretching it on the stilette in the same way as described, can be substituted for the ½-in. tube; that an abscess deep in the liver can be as readily opened, and with as little risk, as one lying near the surface; that the shock is much less than in the cutting and tearing operation; that there is no risk of pneumothorax should the pleural cavity be traversed; and that the drainage obtained is equal to that secured by any other method of operating. Several of my surgical friends have adopted this method of operating, and have expressed great satisfaction with the ease with which it is performed, and with the results.

Other operations. — Some Continental surgeons recommend extensive incision of the liver, using a Paquelin's knife with the view of minimizing bleeding. Zancarol, for example, advises that the hepatic and integumental incisions should extend the whole breadth of the abscess cavity, which he mops out and

stuffs with iodoform gauze. Certain French surgeons recommend scraping the abscess cavity; most practise irrigation with some antiseptic fluid. These methods do not find favour with English or Indian surgeons.

The method of opening the abscess by caustics, formerly much in vogue, is now abandoned; equally so another method, also formerly employed—namely, that of leaving a rigid trocar in the wound.

Treatment after operation.—For the first few days after a liver abscess has been opened the discharge is considerable, and the dressing may have to be changed frequently. Very soon, however, should the case do well, the discharge rapidly diminishes, and the dressing requires renewal only every other day or every three or four days. During the first week the drainage-tube, provided it be acting efficiently, should not be disturbed, more particularly as it may be difficult to replace. Later, it may be removed and cleaned, and, when discharge has practically ceased, cautiously shortened. *It is a great mistake to begin shortening the tube before it is being pushed out, or so long as there is any appreciable discharge.* If there is the slightest indication, such as rise of temperature, that pus is being retained, the drainage must be rectified and the sinus, if necessary, dilated with forceps and finger, and a full-sized drainage-tube introduced as far as it will go. If this does not suffice, a counter-opening may have to be made. *Delay in remedying imperfect drainage is a serious, it may be fatal error.*

Should an abscess on being opened be found to be septic, or should it become so, it must be flushed out daily, or twice a day, with a weak non-mercurial antiseptic, and a counter-opening made if necessary. Quinine solution—1 in 1,000 normal saline—is useful if much amœba-laden discharge persists for a length of time.

After liver abscess has been opened and is draining well, temperature rapidly falls, and in a few days, or almost at once, becomes normal. Should fever persist, it is to be inferred either that the drainage is inefficient, or that there are more abscesses in the liver, or that there is some complica-

tion. If it be deemed that there is another abscess, this should be sought for with the aspirator, and, if found, opened and drained. I have seen a patient recover after three abscesses had been so treated.

It is advisable to give emetine* hypodermically, both before and after operation. Lately cases of liver abscess have been successfully treated by emptying the abscess by aspiration and injecting the cavity with emetine solution.

Treatment of abscess discharging through the lung.—In the case of abscess discharging through the lung, and, although emetine has been freely administered, not progressing favourably, the question of obtaining by surgical means more efficient drainage must be considered. There are two possibilities which render interference desirable: (*a*) Continued discharge of pus and blood, with or without attendant hectic; a condition which, if it persist, will, in all probability, in the end kill the patient. (*b*) Not infrequently prolonged discharge through the lung may induce fibrotic changes in that organ, or may give rise to pneumonia, or to abscess of the lung with all its attendant dangers, such as thrombosis or abscess of the brain. In these circumstances it is sometimes difficult to arrive at a decision as to whether an attempt should be made to open and drain the abscess, or to leave it alone. A large proportion of the cases recover, but at least an equally large number die. Of the latter, a proportion may certainly be saved by timely surgical interference.

In all cases of abscess discharging through the lung a careful register should be kept of three things —body temperature, daily amount and character of expectoration, and, once a week, the weight of the patient. If temperature keeps up, if the amount of pus continues the same or increases, or if the patient continues to lose weight, an attempt should be made at all risks to reach and drain the abscess from the

* A case has been recorded of a patient who, refusing operation, was completely cured by emetine injections—21 gr. being administered altogether; of another in whom the abscess burst into the lung and all discharge ceased on the administration of emetine.

outside. If temperature keeps normal, if pus gradually or intermittently decreases, and if the body-weight is maintained or increases, operation is unnecessary, or, at all events, should be deferred.

In exploring the liver in such cases it must be borne in mind that most likely the abscess cavity is collapsed, and that the sides of the abscess may be in contact. Such an abscess is not likely to be discovered unless the needle be thrust in to its full extent, and, whilst a good vacuum is being maintained in the aspirator, slowly withdrawn. If by good fortune the abscess has been traversed, then, when the end of the needle is crossing the cavity, a small amount of pus will be seen to flow. Great care must now be exercised to keep the needle in position so as to serve as a guide in opening the abscess. Recovery has been known to follow the introduction of a drainage-tube in the presumed direction of such an abscess, even although the abscess cavity was not entered, much less drained by the tube.

Treatment of abscess rupturing into a serous cavity.—When there is evidence that an abscess of the liver has ruptured into the peritoneum, into the pleura, or into the pericardium, the particular serous cavity involved must be opened at once and treated on general surgical principles; otherwise the patient will almost surely die. In the circumstances the surgeon will be justified in assuming great risks.

The *prognosis in early operations* on single abscess of the liver, provided there is no dysentery or other complication, is good. In multiple abscess, or in single abscess if there is active dysentery or other serious complication, prognosis is bad. In multiple abscess, if there are more than two or three abscesses, it is necessarily hopeless.

The *question of return to the tropics* after recovery from liver abscess frequently crops up. If feasible, and if the patient has not to make too great a sacrifice, he ought to remain in a temperate and healthy climate. There are many instances, however, of individuals who have enjoyed permanent good health in the tropics after recovery from liver abscess.

CHAPTER XXXV

INFANTILE BILIARY CIRRHOSIS

WITHIN the last three decades a peculiar disease of the liver has been noticed in children in Calcutta and, to a less extent, in other large towns of India. It is found to be more prevalent in Hindu than in Mohammedan children. Thus, in Calcutta, from 1891 to 1893 inclusive, infantile biliary cirrhosis, the name given to this disease, caused 1,748 deaths. Although the Hindu and Mohammedan populations of that city are about equal, yet as many as 1,616 of the deaths occurred in Hindus, whilst only 80 occurred among Mohammedans, the balance of the mortality being among the Eurasians and other races. The disease occurs principally in children under one year, rarely attacking those over three years. As a rule, it commences during dentition, or about the seventh or eighth month, running a fatal course in from three to eight months. In rare cases it may commence within a few days of birth. Instead of lasting several months, its progress may be much more rapid, and terminate in death in from two to three weeks.

The cause of infantile biliary cirrhosis is quite unknown. Neither alcohol, syphilis, nor malaria has anything to do with it. The children of the well-to-do are relatively more frequently attacked than those of the poor. It has also been observed that it tends to run in families, child after child of the same parents succumbing within a year or two of birth. In 400 cases Ghose had only six recoveries; in some of these recoveries the diagnosis was doubtful.

Symptoms.—Commencing insidiously, the characteristic initial enlargement of the liver may have made considerable progress before the disease is suspected. Nausea, occasional vomiting, sallowness,

feverishness, constipation, anorexia, irritability of temper, thirst and languor call attention to the child's condition. On examination the liver is found to be enormously enlarged, extending perhaps to the umbilicus or even lower. The surface of the organ is smooth; the edge, at first rounded and prominent, as the liver begins to contract becomes sharp and distinct and can be readily grasped between the fingers, the swollen organ feeling hard and resistant. Fever of a low type sets in; the sallowness deepens into profound jaundice; the stools are pale, the urine is dark; and there may be ascites, with puffiness of the feet and hands. Sooner or later, death from cholæmia ensues.

Pathological anatomy and pathology.—Surgeon-Major Gibbons, who has given an elaborate and most careful account of the pathological anatomy of this disease, concludes that it is a peculiar form of biliary cirrhosis, the consequence of the action on the liver cells of some irritant of gastric origin, which leads to degeneration of the cells in the first instance, with subsequent increase of intercellular connective tissue and, later, of the portal sheaths. The formation of new bile-ducts between the hepatic cells, which is a well-marked feature, he regards as evidence of a natural curative effort having for its object a regeneration of the liver cells.

Treatment.—Hitherto, in this disease, treatment has been of little avail. There is some ground, however, for thinking that early removal from the endemic locality, and a complete change of wet-nurse and food, might have a beneficial effect.

Section IV.—INFECTIVE GRANULOMATOUS DISEASES

CHAPTER XXXVI

LEPROSY (ELEPHANTIASIS GRÆCORUM)

Definition.—A chronic infective granulomatous disease produced by a specific bacterium, and characterized by lesions of the skin, nerves, and viscera eventuating in local anæsthesia, ulceration, and a great variety of trophic lesions. After a long course it is almost invariably fatal.

History.—The many allusions in the oldest Chinese, Indian, Syrian, and Egyptian writings to a chronic, disfiguring, and fatal affection possessing well-marked and characteristic skin lesions, warrant us in concluding that the disease now known as leprosy was as common and familiar in the East in times of remotest antiquity as it is at the present day.

There is some evidence—necessarily of a negative character—that leprosy is of comparatively recent introduction into Europe. The earlier Greek and Latin writers do not mention the disease. Hippocrates, who, had he been practically acquainted with leprosy, would undoubtedly have described it accurately and fully, makes but brief allusion to the subject. Aristotle is the first of the Greek writers to give an unequivocal description. We may infer, therefore, that the introduction of leprosy into Greece probably took place between the time of Hippocrates and that of Aristotle—that is to say, between 400 B.C. and 345 B.C. Most likely it came from Egypt. In the time of Celsus—53 B.C. to A.D. 7—it was still a rare disease in Italy; but during the earlier centuries of our era it increased there, and, probably following in the wake of the Roman conquests, it appears to

have spread thence over the greater part, if not over the whole, of Europe. By the end of the seventh century it was well known in Spain, France, and Lombardy. There is a notice of its occurrence in Ireland in 432. As regards England, the first allusion to leprosy refers to about the year 950. The popular idea that it was brought to this country from the East by the returning Crusaders (*circa* 1098) is therefore incorrect; though, doubtless, the Crusaders, and the multiplicity of pilgrimages so much the fashion in the Middle Ages, and the destitution arising from the many wars of the period, had something to do with its rapid diffusion and great increase about this time.

So common was leprosy during the Middle Ages that the rulers and clergy of nearly all European states, becoming alarmed at its rapid extension and terrible ravages, took measures, by instituting leper asylums and enacting stringent laws for the segregation and isolation of lepers, to restrict the spread of what was speedily becoming almost a general calamity. These measures, based on what we now know to be a correct appreciation of the infectious nature of the disease, were ultimately crowned, in the case of most European countries, with almost complete success. Reaching its acme during the fourteenth century, leprosy then began to decline, although as regards Great Britain it did not finally disappear as an indigenous disease until the end of the eighteenth century. It died out first in England, later in Scotland—the last British leper dying in Shetland in 1798. In Italy, France, Spain, Germany, and Russia the repressive measures were almost equally successful, although in these countries, in Greece, and in the Greek islands leprosy of indigenous origin is still occasionally to be seen. The only country in Northern Europe in which at the present day it may be said to linger to any extent is Norway, where, in places, it is still by no means uncommon (in 1890 there were 1,100, in 1906 under 500 known lepers); but even here, under a system of segregation and comparative isolation—more humane perhaps in its application than that

practised by our ancestors, although identical with it in principle—the disease is rapidly dying out.

Apart from Egypt, we know nothing of the early history of leprosy in Africa. We are equally ignorant as regards aboriginal America. The historians of the Spanish Conquest do not allude to it as a native disease; we appear, therefore, to be justified in concluding that the introduction of leprosy into the New World was probably effected by the Spaniards, or through the negroes in the days of the slave trade.

Rise of modern knowledge of leprosy.—The more important landmarks in our modern knowledge of leprosy are, first, the publication in 1848 of Danielssen and Boeck's "Traité de la Spedalskhed," in which, for the first time, the clinical features of the disease were carefully and critically described; second, the descriptions of the macroscopic and microscopic lesions—the leproma, the nerve lesions, and the lepra cell—by Virchow, Vandyke Carter, and many others; and last, the discovery in 1874 by Armauer Hansen of the specific cause of leprosy—the *Bacillus leprœ*—a discovery which brings this disease into line with tuberculosis, and has given a much-needed precision to our ideas on the important subjects of heredity and contagion, and on other practical points bearing on the question of the leper as a source of public danger and on his treatment and management.

Geographical distribution.—Whatever may have been the case formerly, at the present day, with unimportant exceptions, leprosy is a disease more particularly of tropical and sub-tropical countries. So generally is it diffused in these that it would be more easy to specify the tropical countries in which leprosy has not, than to enumerate those in which it has been ascertained to exist. Moreover, it is probable that in many of the countries not yet positively known to harbour the disease it does really exist; for experience shows that the endemic area of leprosy enlarges as our knowledge of the natives of the uncivilized regions of the earth becomes more intimate. It may be safely concluded,

therefore, that with the exception of a few insignificant islands, leprosy is an element, and often an important element, in the pathology of nearly all warm countries.

The only tropical country of any magnitude about which we have anything like accurate leprosy statistics is India; and even in this instance the figures for many reasons—principally errors in diagnosis and concealment—are untrustworthy. According to the census of 1891, after making allowance for error, it is estimated that in British India there were 105,000 lepers in a population of 210,000,000—a ratio of about 5 in 10,000. Respecting China, of all countries probably the one in which there is the largest number of lepers, we have no figures to go by; but, judging from what is seen in the coast towns and treaty ports, the number of lepers is probably sensibly greater than in India. In Japan, in the Philippines, in Cochin China, in the Malay peninsula, in the islands of the Eastern Archipelago and of the South Pacific, in Persia, Arabia, and Africa, the disease is common enough. The same may be said of the West Indies and of the tropical regions of America.

As regards more temperate countries, we know that there are a considerable number of lepers at the Cape, a few in Australia (principally Chinese, but also a few Europeans), a few in San Francisco (Chinese). In Canada and in the United States there are also a few lepers of European blood, but their number is quite insignificant. In New Zealand, where leprosy used to be common among the Maoris, it has died out. There are a good many lepers in Iceland. Leprosy is also reported as existing among the aborigines of the Aleutian peninsula and Kamtchatka. In Great Britain and other European countries, particularly in the capital cities, lepers are not infrequently exhibited at medical societies; but, with rare exceptions, these cases are not of indigenous origin, most of them having contracted the disease abroad.

Though thus extensively diffused, leprosy is by no means equally prevalent throughout the wide area

indicated. Thus in China it is comparatively rare in the northern provinces, excessively common in the southern. In India a similar caprice of distribution is noted; in Burdwan, for example, the proportion of lepers in 10,000 of the population is as high as 19·5, whereas in several other districts it is as low as 1·5, or even lower. This caprice of distribution does not seem to depend directly on climate, geological formation, or such-like physical conditions; for leprosy is found in mountainous districts, on the plains, on the coast, in the interior, in all varieties of climate, and on all kinds of geological strata. Social conditions, it would seem, have most to do in determining distribution; its endemic prevalence appearing to be bound up in some way with uncleanly habits, squalor, dirt, and poverty —not, be it noted, directly caused by these things, but associated with them.

Recent introduction.—An interesting and, from the etiological standpoint, an important circumstance about the geographical distribution of leprosy is its appearance and rapid spread in recent times in certain islands whose inhabitants, there is good reason to believe, had previously been exempt. This modern introduction of leprosy into virgin soil, so to speak, has taken place in the Sandwich Islands, in New Caledonia, and elsewhere.

Sandwich Islands.—In the case of the Sandwich Islands leprosy was noted among the aborigines for the first time in 1859. After the most painstaking investigation Dr. Hildebrand failed to trace it farther back than 1848. Soon after its presence was recognized the disease spread so rapidly that by the year 1865 there were 230 known lepers in a population of 67,000. By 1891 the native population, from various causes, had diminished to 44,232; of these 1,500 were lepers—about 1 in 30.

New Caledonia.—In New Caledonia leprosy was unknown until 1865. It is supposed to have been introduced about that time by a Chinaman; the man was well known. Its rapid diffusion throughout the island can be, and has been, traced step by step. In 1888 the lepers numbered 4,000.

Isle of Pines.—Similarly, in the Isle of Pines leprosy was introduced in 1878, and has since spread. In the Loyalty Islands the first case was seen in 1882, in 1888, in the island of Mare alone, there were 70 lepers.

Symptoms.—Although, as will afterwards be explained, the *Bacillus lepræ* is the cause of all leprosy, the clinical manifestations of its presence are far from being identical in every case; indeed, they are almost as varied as are those of syphilis or of tubercle. Our early conceptions of the disease, derived for the most part from the Bible or poetical literature, in which the leper is symbolical of all that is loathsome and hopeless, are apt to mislead. As a matter of fact, in its earlier stages leprosy is far from being always, or even generally, a striking disease. Often for years the only visible evidence of its existence may be two or three small blotches, or perhaps one or two patches of pale or pigmented skin on trunk or limbs—very likely concealed by the clothes and perhaps disregarded by the patient himself—the true significance and nature of which can be appreciated only by the expert. It is generally not until the later stages that we see the disfiguring and extensive lesions on which the popular conception is founded. As a rule, leprosy is a disease of very slow development. Sometimes, it is true, it is suddenly and frankly declared from the outset, and progresses rapidly; but in the vast majority of cases the early lesions are trifling and are apt to be misinterpreted and overlooked, and years elapse before serious mutilation or deformity is produced. The student must bear this important practical fact in mind in the study and diagnosis of all equivocal skin lesions in persons residing in or coming from the endemic haunts of leprosy.

To facilitate description, it seems advisable to divide the evolution of leprosy into stages, premising, however, that the division proposed is in great measure an artificial one. What are here designated stages are not, all of them, clinically and in every instance, abruptly separated or even present; for the

most part they merge imperceptibly into each other and, in not a few instances, some of them cannot be recognized.

1. Primary infection.
2. Period of incubation.
3. Prodromata.
4. Primary exanthem or macular stage.
5. Period of specific deposit.
6. Sequelæ—ulceration, paresis, trophic lesions.
7. Terminations.

1. *Primary infection.*—Seeing that leprosy is caused by a specific germ, there must have been a time, in the history of every leper, when the infecting germ entered the body. In many specific diseases, such as syphilis, the site of the primary infection is indicated by a well-marked local lesion, and the time of infection can usually be ascertained. So far as present knowledge goes, this much cannot be affirmed of leprosy; in this disease we know of nothing that indicates precisely either the seat or, with rare exceptions, the time of primary infection. In this respect leprosy resembles tuberculosis. We are equally ignorant as to the condition of the infecting germ, whether it enters the body as spore or as bacillus, and also as to the medium in or by which it is conveyed. We cannot say whether it enters in food, in water, in air; whether it passes in through the unbroken epithelium, or whether it is inoculated on some accidental breach of surface, or, perhaps, introduced by some insect bite.

Sticker has found *Bacillus lepræ* in the nasal mucus in 128 out of 153 lepers examined. He considers that the initial lesion of the disease is a specific ulceration of the cartilaginous septum of the nose; the lesion persists and is an active source for the diffusion of infection. Of the presence of this condition, epistaxis, he maintains, is often an early symptom. Several subsequent observers favour this view.

Although we are in absolute ignorance as to the process of infection, we may be quite sure that in leprosy there is an act of infection, and that the

infective material comes from another leper. Leprosy has never been shown to arise in a country *de novo*. There are many facts and arguments to support this statement; their discussion is deferred until the subjects of heredity, contagion, and the hygienic questions connected therewith, come to be considered.

2. *The period of incubation.*—This is generally, possibly always, long, and has to be reckoned usually in years—two or three at least. There are cases on record in which the period of incubation must have been longer even than this. Danielssen mentions one in which the period was ten years, Leloir describes another in which fourteen years or more, and Höegh one in which twenty-seven years elapsed between the time at which infection was presumed to have occurred and the first manifestations of the disease. On the other hand, cases are on record in which the incubation period was set down at three months or even at a few weeks.

3. *Prodromata.*—Fever of greater or less intensity and occurring more or less frequently is, almost invariably, a feature of the prodromal stage of leprosy. Febrile attacks may recur off and on during one or two years. It is well to bear in mind that in tropical countries such attacks are apt to be looked on as malarial. Another very common prodromal feature is an unaccountable feeling of weakness, accompanied usually by a sensation of heaviness and a tendency, it may be irresistible, to fall asleep at unusual times. Dyspeptic troubles, associated with diarrhœa in some cases, with constipation in others, and usually attributed to "liver," are also common. Epistaxis and dryness of the nostrils, perhaps symptomatic of the initial lesion, perhaps corresponding to the epistaxis in the prodromal stage of typhoid, tuberculosis, and such as is sometimes met with in early syphilis, are noted by Leloir. Headache; vertigo; perversions of sensation—such as localized pruritus, hyperæsthesia, "pins and needles," neuralgic pains—intermittent for the most part, and perhaps very severe and especially common in the limbs and face; general aching, rheumatic-like pains in loins,

back, and elsewhere; all or any of these for months may herald the explosion of unequivocal leprosy.

Another curious feature in early leprosy, also noted by Leloir, is the liability in many instances to excessive sweating, which comes on without apparent or on very slight provocation. I had once under observation an Englishman who subsequently developed leprosy, in whom this prodromal symptom was particularly pronounced, so pronounced that he had remarked it himself. This gentleman for many years kept a diary in which, among other things, he recorded very carefully matters relating to his health; so that it was easy to trace from this diary the gradual evolution of his leprosy. The first unequivocal manifestation of the disease, an extensive erythematous patch on the ulnar side of the left arm and hand, which afterwards became anæsthetic, and two or three pigmented spots on the cheek, back, and leg, was noted on March 3rd, 1894. Five years before this there is an entry in his diary, under date June 4th, 1889, of the first of a long series of severe headaches, transient febrile attacks, and progressive deterioration of health and vigour. Under date of June 9th, 1892, is the first mention of the profuse perspiration which, occurring without obvious cause, continued to be a prominent feature until several months after the appearance of the skin lesions referred to. In the diary such entries as the following frequently occur: "Nov. 20th, 1892.—Feel poorly and sweating inordinately; wondering what is coming over me. I am very ill." "Dec. 5th to 19th, 1892.—Ill in bed. I had furious sweats during this time, and had dreadful pains in the back, the lower part." And again: "Dec. 21st, 22nd.—Feeling very ill: awful sweats; weak; done up." As pointed out by Leloir, this hyperidrosis may be general or it may be confined to particular parts, generally the trunk, the limbs being unaffected or even being the subject of anidrosis. A still more limited anidrosis is sometimes noted; it usually happens that these non-sweating spots become anæsthetic at a later period of the disease.

Just as in syphilis, in a very small proportion of cases of leprosy there is a complete absence of constitutional symptoms prior to the appearance of the specific skin eruption.

4. *The primary exanthem.*—In a considerable proportion of cases, after a longer or shorter period of indifferent health, sometimes preluded by an outburst more severe than usual of fever and other prodromal phenomena, an eruption appears on the skin. This generally coincides with, or is soon followed by, an improvement in the general health.

Although strictly macular, this eruption—the primary exanthem of leprosy—varies in different cases as well in respect of the size of the spots as of their number, duration, and other characteristics. They may be no larger than a millet-seed, or they may occupy surfaces many inches in diameter; they may be numerous, or there may be only two or three. The earlier spots are usually purely erythematous, disappearing on pressure, and being darkest in the centre and shading off towards the periphery. But in some cases they may be pigmented from the outset; or they may be mere vitiliginous patches; or all three forms of macula may concur in the same individual—erythematous, pigmented, and vitiliginous. In not a few lepers what in the first instance was an erythematous patch may in time become pigmented, or it may become pale; in the latter case the loss of pigment is usually associated with a certain degree of atrophy of the cutis. Or it may be that the centre of an erythematous patch clears up, the periphery of the patch remaining red and perhaps becoming pigmented: so that the affected spot comes to present the appearance of a red or dark ring, or portion of a ring, enclosing a patch of pale, usually anæsthetic skin. In certain instances the eruption of the various forms of maculæ may be preceded by local paræsthesiæ, such as a sense of burning, tingling, pricking, and so forth.

At first the maculæ may be evanescent and may fade wholly or in part in the course of a few days, weeks, or months; but as the disease progresses, and

fresh spots appear, they tend to greater permanency, to be more liable to pigmentation, and are partially or wholly anæsthetic from the outset, or subsequently become so.

A striking feature of this and of all leprous eruptions is the loss of the hair in the affected areas. Another striking circumstance is the fact that the most hairy part of the body, the scalp, is never or very rarely affected either with leprous eruptions or with leprous alopecia. As the face, particularly the superciliary region, is prone to all forms of leprous eruption, falling of the eyebrows is a very usual, very early, and very characteristic phenomenon. The beard, too, is apt to be patchy, particularly in nodular leprosy. In many instances, before they drop out, the individual hairs become white, or downy, or splintered, or monillated.

The most frequent seats of the primary macular eruption are the face, especially the superciliary region, the nose, cheeks, and ears; the extensor surfaces of the limbs; the backs of the hands; the back, buttocks, abdomen, and chest. The palms of the hands and the soles of the feet are rarely if ever attacked. At this stage of the disease the mucous membranes are very rarely affected.

In the distribution of the maculæ a rough symmetry may or may not be discernible.

5. *The period of specific deposit.*—During the stage just described, if there be any thickening of the skin or other evidence of new growth, it is barely perceptible to sight and but slightly so to touch. Sooner or later, however, another stage is entered on, a stage characterized by the deposit or, rather, growth of a tissue possessing well-marked specific characters. This deposit occurs either in the skin, or in the continuity of the peripheral nerve trunks, or in both. If in the first situation, nodular or, as it is sometimes called, tubercular leprosy is the result; if in the second, we have nerve or anæsthetic leprosy; if in both of these situations, then what is known as "mixed leprosy" is produced. These three forms of the completely developed disease, though having much in common,

are, as a rule, clinically fairly distinguishable. It is customary, therefore, to describe them separately.

Nodular Leprosy

This form of leprosy often appears without a well-marked preliminary macular stage, being ushered in, after a longer or shorter prodromal stage, by a smart attack of fever and the rapid development on

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Fig. 85.—Nodular leprosy. (*After Leloir.*)

the face or elsewhere of the specific lesion. In other instances a well-defined but, in comparison with nerve leprosy, short macular stage precedes the appearance of the characteristic lepromata (Fig. 85).

The essential element in nodular leprosy is the leproma. The dimensions, the combinations, the situations, the growth, and the decay of this give rise to the more manifest symptoms of the earlier stages, at all events, of the disease. The leproma, which will be more fully described in the section on

the pathological anatomy of leprosy, is formed by infiltration of the deeper layers of the derma with what at first is a small-celled, somewhat dense neoplasm. As this slowly or more rapidly increases it forms a prominent, rounded boss or protuberance covered with unbroken epidermis. In size it ranges from the dimensions of a split pea, or of a bean, to a great plaque many inches across. In colour it differs according to its age and condition, and according to the natural hue of the skin of the leper; it varies from red to dirty pink in the earlier and congestive active stage, to dark brown or dirty yellow in the later stages. It is generally—though not always, especially at first—anæsthetic to some degree, if not absolutely so; it is devoid of hair, usually somewhat greasy-looking and, perhaps, stippled with gaping sebaceous follicles. Though not so hard as cheloid growth, it is fairly firm to the touch, and, unless very extensive, can be readily raised up and freely moved over subjacent structures. Isolated lepromata are usually round or oval; when contiguous they may coalesce, forming patches of irregular outline.

When many lepromata run together, or are closely set, the growth causes the natural folds of the skin to be exaggerated; great disfigurement, especially of the face, may ensue. Thus the skin of the forehead and eyebrows—an early and favourite site of leprous infiltration—is thrown into massive folds and overhangs the eyes; the fleshy parts of the nose broaden out; the cheeks become massive; the lips are thickened and protrude; the chin is swollen and heavy; the external ears are thick and pendulous; and the bloated, dusky, wrinkled, greasy, passive countenance acquires the repulsive appearance very appropriately designated "leontiasis."

Nodules may appear in greater or less profusion on the limbs and body; favourite sites being the backs of the hands, the external surfaces of the arms, wrists, thighs, and the groins. On the trunk they may occupy very large areas, forming extensive plaques. As a rule, in the latter situation they are not so prominent as on the face and arms. The same remark

applies to the legs, where the infiltration is usually dusky, diffuse, ill defined, and prone to ulcerate.

From time to time, and at longer or shorter intervals, fresh lepromata appear, their formation generally concurring with an outburst of fever. Occasionally—and this is very often observed during an intercurrent attack of some acute disease, such as an exanthematous fever, or erysipelas, or even of some exhausting disease like phthisis—all or a proportion of the nodules are temporarily absorbed, leaving only slight traces behind. But the normal and usual fate of the nodule is either first to soften in the centre and then to be absorbed, leaving a smooth circular patch of scar tissue; or, after softening, to ulcerate and discharge a sticky, yellowish pus. This discharge tends to dry up into crusts, ulceration proceeding underneath. Finally the ulcer may heal, leaving an irregular, depressed scar.

When the septum of the nose is affected, the cartilage breaks down, the tip of the organ becomes depressed, and a stinking discharge escapes from the nostrils. In such circumstances breathing is very much interfered with, more especially if, at the same time, leprous deposit occurs or ulcerates in or about the glottis, the epiglottis, pharynx, tongue, or mouth generally. The senses of smell and taste are then lost for ever.

The eyes, also, are sooner or later attacked, lepromatous growth spreading from the conjunctiva on to the cornea or into the anterior chamber, or originating in the iris or ciliary body. Ultimately these organs also are destroyed.

Thus, in time, with the exception of that of hearing, one sense after another is lost. Ulcers form everywhere from the breaking-down of the nodules or from injuries to the insensitive skin. The cervical and inguinal glands, owing to leprous infiltration, swell and perhaps suppurate and become fistulous; the abdomen enlarges from leprous, perhaps combined with amyloid infiltration of the liver, and there may be diarrhœa from amyloid disease of the intestine. In addition to these troubles, if the patient

live, the nerve trunks are attacked, and then the neuralgic, paretic and trophic lesions of nerve leprosy are superadded. The fingers and toes ulcerate and drop off, or they become distorted and atrophied; or the phalanges are absorbed, the hands and feet becoming reduced to useless stumps. A peculiar goat-like smell is emitted by the ulcerating, decaying body. Altogether, the blind, lame, and unhappy wretch—still retaining his intellect, but devoid of every sense except that of hearing, breathing with difficulty through a stenosed larynx, and racked by neuralgic pains and irregular outbursts of fever—comes to present, before the inevitable death from exhaustion occurs, a sadder, more loathsome, and more repulsive picture than anything imagination could conceive. Fortunately, in a large proportion of cases, the leper is mercifully carried off by phthisis, pneumonia, or some intercurrent affection at an earlier period, and before his disease can be said to have run its full course.

Nerve Leprosy

Just as in nodular leprosy, in nerve leprosy the prodromal and macular stages may be severe, or slight, or altogether absent. Usually, however, in nerve leprosy, much more frequently than in nodular leprosy, the ulterior and more distinctive lesions are preluded by a long and well-marked macular stage, during which large areas of skin are occupied by erythematous (Fig. 86), by pigmented, or by vitiliginous patches. The ringed form of eruption is a very usual one; a red, congested, slightly elevated and, perhaps, hyperæsthetic border enclosing a larger or smaller area of pale, anæsthetic, non-sweating integument—the whole resembling somewhat one of those extensive body-ringworms so common in natives of hot, damp climates, and for which these rings are sometimes mistaken. Such eruptions may come and go, or they may be permanent, or they may spread and multiply during many years before the more distinctive and graver signs of nerve leprosy are evolved.

Fig. 86.—Nerve leprosy. (*After Leloir.*)

A frequent and very distinctive symptom of this type of the disease, occurring often about this time, is the sudden appearance of bullæ (pemphigus leprosus) —one or more or a series of them—on the hands, feet, knees, backs of thighs, or elsewhere. These bullæ vary in size from a pea to an egg. After a few days they rupture, exposing a reddish surface which presently crusts over, exfoliates, and finally turns into a pale, perhaps anæsthetic spot with a sharply defined, pigmented border. More rarely the site of the bulla ulcerates. Should similar bullæ be formed in the neighbourhood of the first, the resulting ulcerations may unite into an extensive, probably superficial, serpiginous-looking sore.

A time comes when evidence of profound implication of the nervous system, in the shape of severe neuralgic pains, formication, hyperæsthesia, or anæsthesia, becomes more accentuated. The lymphatic glands enlarge, and there is often considerable fever and general distress. Hitherto the most prominent symptoms have been the skin lesions. These may remain or even increase; on the other hand, they may in part or entirely disappear. But whether the skin lesions increase or retrograde, evidences of profound implication of the peripheral nervous system now distinctly show themselves; the neuralgic pains still further increase, and hyperæsthesia, anæsthesia, and various paræsthesiæ, along with trophic changes in skin, muscle, and bone, the results of nerve destruction, become the dominating elements in the case.

If at this stage the ulnar nerve where it passes round the internal condyle of the humerus be examined, generally it will be found to be the seat of a fusiform swelling, perhaps as thick as the little finger. Other nerves, such as the anterior tibial, the peroneal, more rarely the median, radial, brachial, and cervical nerves, especially where they pass over a bone and lie close under the skin, can be felt to be similarly swollen. Occasionally even the smaller nerves, where superficial, can also be detected hard and cord-like. At first these thickened nerves are tender on pressure, and the parts they supply may be the seats

of hyperæsthesia and acute neuralgia. By degrees the great thickening of the nerve trunks decreases somewhat, the hyperæsthesia and neuralgia subside, and anæsthesia, paresis, muscular atrophy, and other trophic changes take their place. For a time the condition may fluctuate; the neuritis apparently may come and go with corresponding changes in the condition of the area subserved by the affected nerves. Sooner or later, however, fibrotic changes ensue in the neural leprous deposits, and the nerve tubules ultimately atrophy and disappear. The nerve tissue is now irreparably damaged, and trophic changes steadily advance. In other instances anæsthesia comes on without neuralgic pains, without hyperæsthesia, without constitutional symptoms, without discoloration of the skin, the patient discovering its existence by accident.

In nerve leprosy the anæsthesia begins most commonly in the feet, the thighs, hands, arms, forearms, and face. Later, and more rarely, it affects the trunk. The anæsthesia, though associated with well-marked lesions of the larger nerves, does not always, or even as a rule, coincide accurately with the anatomical distribution of their terminals; a circumstance which tends to show that the anæsthesia is not always and simply the result of lesion of nerve trunks, but that it may be the effect of the destruction by the bacillus of the nerve terminals themselves; a suggestion which is strengthened by Gerlach's discovery that in anæsthetic leprosy the bacilli appear first in the skin around the nerve terminals, and only subsequently extend upwards to the nerve trunks. Another, and sometimes a very striking fact in nerve leprosy is the symmetry observed in the distribution of some of the anæsthetic areas. This symmetry is by no means invariable; in not a few cases, however, it is very perfect and remarkable.

At the outset the anæsthesia in the affected patches may not be absolute; it may also come and go; and it may be very superficial, deep pressure being for a long time appreciable. But when the

anæsthesia becomes, as it were, settled in a part, it seems gradually to extend deeper into the tissues; so that after a time it is absolute, and the part may be pinched, incised, and even seared with fire, and the leper be absolutely unconscious of pain or even of being touched.

Step by step with the progress of the anæsthesia, atrophy of the subjacent muscles supplied by the thickened nerves proceeds. Along with the atrophy there is a corresponding distortion and a corresponding loss of power. There is no ataxia or incoordination of movement—simply feebleness. Thus the forearm wastes, the grasp is weakened, the thenar and hypothenar eminences and the interossei melt

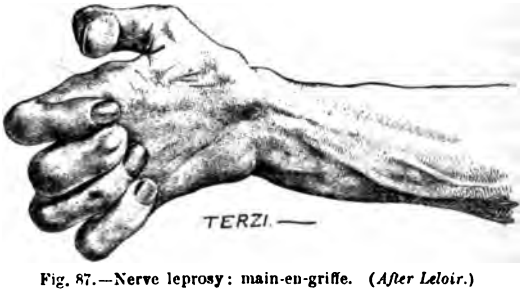


Fig. 87.—Nerve leprosy: main-en-griffe. (*After Leloir.*)

away, and the *main-en-griffe* or some such deformity is gradually produced (Fig. 87). Similar changes occur in the legs and feet, so that the power of walking is much impaired. The muscles of the thighs and upper arms, the pectorals, and the muscles of the face follow suit very much as in progressive muscular atrophy, only in the latter disease there is no superjacent anæsthesia.

In the affected nerve areas all the muscles are not simultaneously or equally attacked, so that, especially in the face, curious distortions may ensue. These facial atrophies, whether symmetrical or one-sided, in time produce a facies as characteristic of nerve leprosy as leontiasis is of nodular leprosy. Owing to muscular atrophy, the eyes, after a time,

cannot be closed; the upper lid droops, the lower lid becomes everted, and the eye itself may become fixed. At first, owing to exposure of the organ, there is lachrymation; but by and by the secretion of tears dries up, the congested conjunctiva becomes cornified, the cornea ulcerates or turns leucomatous, and in the end sight is entirely lost. Ulceration often occurs in the mucous membrane of the nose, the septum being destroyed as in the nodular form; the tip of the nose may then fall down or be entirely lost. The lips, too, may become paralysed, thereby interfering with articulation and permitting the saliva to dribble from the mouth in a constant stream. Changes occur, too, in the mucous membrane of the mouth; the gums may retract, exposing the maxillary bone, the teeth ultimately dropping out. Anæsthesia of the tongue and buccal mucous membrane, and implication of the muscles of mastication, may render eating and articulation very difficult.

In time the skin of anæsthetic patches on the limbs tends to atrophy; it loses its glands and hairs, and, in the end, may become so thinned and tense that it actually bursts into long cracks. The nails are not generally shed, but they become rough, or thinned, or atrophied into minute, hook-like appendages.

Ulcers form over exposed parts of the hands and feet. They may penetrate and disorganize the joints, and thus often cause fingers and toes to drop off, one after another. Or, perhaps, an abscess forms around a phalanx, destroys the periosteum, and ultimately leads to loss of the bone. Or a sort of dry gangrene may amputate finger or toe. Or there may be a curious interstitial absorption of one or more phalanges, the shaft of the phalanx wasting more rapidly than the articulating surfaces. In any of these ways the fingers and toes are distorted or destroyed. It is no unusual thing to see on a leper's hand a finger in which one or more of the phalanges have been thus got rid of without destruction of the fleshy part, or with only a general shrinking of this. Thus it comes about that a distorted, talon-like nail may crown a finger which is a mere stump; or, the

finger having been entirely absorbed, the nail springs, as it were, directly from the knuckle.

Perforating ulcer of the sole of the foot, usually under the ball of the great toe or the heel, is a very common lesion in nerve leprosy.

On the whole, the advance of this form of leprosy is much slower than that of the nodular variety. The average duration of the latter is from eight to nine years, of nerve leprosy about eighteen years. Often such lepers live much longer—twenty, thirty, or even forty years. The end of these cases is quite as sad and repulsive as that of nodular leprosy. Death seldom results directly from the disease itself, but usually from diarrhœa, chronic nephritis, phthisis, pneumonia, or bronchitis.

Mixed Leprosy

As already explained, in most cases of nodular leprosy trophic changes from implication of nerve trunks ultimately supervene. Similarly, though not so frequently, nodular infiltration of the skin may appear in the course of what originally seemed to be a case of pure nerve leprosy. In yet other cases nodular and nerve lesions concur from the outset. In one or other of these ways what is known as mixed leprosy is produced. The lesions are in no way different from those already mentioned, and therefore this form of the disease does not call for more detailed description.

Pathological anatomy. *Bacillus lepræ.*—The lesions of leprosy are the result, direct or indirect, of the proliferation of the *Bacillus lepræ* in the tissues. This parasite (Fig. 88) in size, shape, and staining reactions closely resembles the bacillus of tubercle. In length it is from half to two-thirds, and in breadth about one-sixteenth the diameter, of a blood corpuscle. The ends of the rod—which is always straight—are in many specimens somewhat attenuated; and in many instances—presumably in old bacilli—a moniliform arrangement of the protoplasm, as if from spore formation or, according to

Hansen, from disintegration, can be detected. By some authorities it is said to possess a gelatinous capsule. In common with *Bacillus tuberculosis* and *Bacillus smegmæ* it retains carbol-fuchsin stains after being treated with mineral acids. It may be distinguished from *Bacillus tuberculosis* by its staining more readily with cold weak solution of carbol fuchsin, and by being decolorized more easily with dilute acids; by the impossibility hitherto experienced of growing it on the usual culture media, and of successfully in-

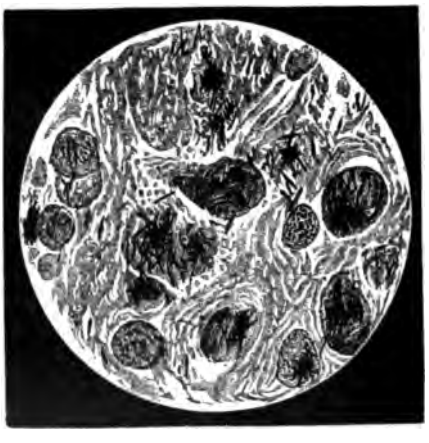


Fig. 88.—Bacillus lepræ. × 1,000. (*Muir and Ritchie.*)

oculating it into man and the lower animals; by its tendency to occur in dense clusters and in greater numbers; and by its very generally being found inside cells or, according to Unna, in zooglœa masses in the lymphatic spaces.

Specimens of the bacillus can be procured readily by excising a portion of a leproma—a proceeding, in consequence of the absence of sensation in most tubercles, not usually much objected to by lepers; or they may be obtained by including a succulent leproma in a pile clamp, slowly screwing up the jaws of the instrument so as to drive out the blood, prick-

ing the now pallid leproma, and then collecting on a cover-glass the droplet of "leper juice" which exudes from the puncture. The juice may be spread out on the cover-glass, fixed, stained, and decolorized as for the demonstration of tubercle bacilli; or it may be examined fresh. Better preparations are obtained by making with a small scalpel a minute incision into the compressed leproma, scraping some of the tissues from the under surface of the skin, and smearing this with the juice on to the cover-glass. One must be careful to exclude the possibility of contamination with *Bacillus tuberculosis*, with which lepers are often infected.

If examined fresh, or if a morsel of leproma be teased up in water, the bacilli may be seen both inside and outside the cells and in active motion. Whether this motion is simply molecular, or whether it is vital, is hard to say; probably the former, for, whilst osmic acid does not stop it, it is immediately arrested by the addition of a viscid fluid, such as glycerine or albumin water.

The bacillus is found in all primary leprous deposits; in the skin leproma—where it occurs in prodigious numbers; in the meagre infiltration of the macular eruptions—where it is much more sparsely distributed; in the early stage of leprous neuritis—where, also, it is present only in small numbers; in the specific lesions of the liver, spleen, testes, lymphatic glands and lungs—where the lesions may resemble those of tuberculosis or may be invisible to the naked eye. In the blood-vessels it has been found in the endothelium and, occasionally, free in the blood or enclosed in leucocytes. It is abundant in the purulent discharges from the nose, from ulcerating lepromata or other forms of primary leprous infiltration. It has very rarely been found in the spinal cord or in the lungs. It is doubtful if it occurs in the brain, the intestinal tract, or in the kidneys, although the latter are prone to inflammation in leprosy. It is not found in muscle, in bone, or in cartilage; and it is not necessarily present in the secondary trophic lesions of nerve leprosy, or in secondary inflammatory effusions.

Many apparently unsuccessful attempts have been made to cultivate the lepra bacillus. I use the word "apparently" because some modern leprologists consider that probably a proportion of these attempts were successful, although at the time not regarded as being so. Mycotic forms developed in the culture media, but as these forms were not acid-fast they were regarded, at the time, as contaminations and not growths of the lepra bacillus.* A modern view is to the effect that *Bacillus lepræ* is really a streptothrix like the actinomyces, or, according to some, the tubercle bacillus, that it is pleomorphic to a high degree, and that at a certain stage of growth and under certain conditions the mycelia break up into short rods, many of which are now acid-fast. There is great discrepancy of opinion among bacteriologists on the subject, each observer having his special lepra germ grown on his special culture medium; this germ he regards as the only true one, conforming, he claims, to the proper agglutination and complement-fixation tests, and its products possessing a therapeutic value comparable to that of tuberculin, and giving rise to a local and a general reaction when injected into lepers. Other bacteriologists, though following the methods that have succeeded in the hands of their authors, have generally failed to obtain similar results.

The discovery that rats (5 per cent. in Paris) are subject to a disease clinically resembling human leprosy may lead to a better knowledge of the lepra bacillus, seeing that the lesions of the "rat leprosy," as it is called, are intimately associated with an acid-fast bacillus resembling that of human leprosy, and that it is communicable to other rats by association.

The leproma.—The young leproma presents a smooth, white, glistening section. When the leproma is older the cut surface has a brown tint, and the morbid tissue may become, from fibrotic changes,

* It is to be noted that recently Fraser, though using the special media recommended by Bayon, Duval and others (placental-juice agar and horse-serum nutrose-agar), and tissue swarming with leprosy bacilli, was unable to obtain any growth after prolonged cultivation.

harder, or, from degeneration, softer. The specific lesion of leprosy differs from that of tubercle inasmuch as the former is well supplied with blood-vessels, contains no true giant cells, and never undergoes caseation. If hardened, cut, stained, decolorized, and examined under the microscope, the leproma is found to consist principally of small round cells about the size of a leucocyte, epithelioid cells, and fusiform cells—the two latter in numbers increasing with the age of the leproma. It can be seen that these cells have infiltrated and partially dissociated all but the most superficial layer of the derma. It may be further observed that the cells are arranged for the most part in groups, generally around and near blood-vessels; and that a very large proportion of them contain bacilli, some cells having only a few, whilst others are literally crammed with the organisms. Isolated bacilli are also found scattered through the preparation, apparently free in the lymph spaces. The bacilli are never seen inside the nuclei of the implicated cells.

In addition to the bacilli-bearing cells, and increasing in number with the age of the lesion, a number of brown granular bodies, larger and smaller, which have been named "globi," are to be found. These Hansen holds to be cells in which the bacilli have perished and become granular. It is to them that the brown colour of old lepromata is due.

There has been considerable discussion as to the exact position of the bacilli as regards the lepra cells —whether they lie inside the cells or whether they are free. On the one hand, Unna holds that they lie free in the lymph spaces, and that they are never in the cells, the appearance of cell inclusion being produced by the zooglœa arrangement so common with bacteria. On the other hand, Leloir maintains that some of the bacilli are free whilst others are inside the cells. A third set of observers, following Hansen, hold that the bacilli are almost invariably included within cells, the nuclei of which can readily be demonstrated surrounded by the parasites.

Other lesions.—The histology of the infiltrated macula is practically the same as that of the leproma,

the number of bacilli, lepra cells, and globi being proportionately fewer. In old maculæ, as in very old lepromata, the bacilli may be hard to find or entirely absent. In the anæsthetic maculæ the terminal nerve fibres are degenerated.

As the fusiform thickening of the larger nerve trunks in nerve leprosy is a secondary inflammation, bacilli may not always be found in it, although at the very commencement of the nerve disease bacilli, both in cells and, according to Leloir, free between the nerve tubules, are present and may even lie in the nerve tubules themselves. In time the affected nerves become mere fibrous cords destitute of nerve tubules.

The anatomy and histology of the various trophic lesions are such as are found in other examples of destructive neuritis, and are in no way peculiar to leprosy; they do not, therefore, call for description here.

In nodular leprosy the liver and spleen are the seat, in many instances, of a peculiar infiltration which, in well-marked examples, may be visible to the naked eye. Fine yellowish-white dots and streaks are seen to occur in the acini of the former. These dots and streaks consist of new growth in which bacilli abound. According to Leloir, the parasites are never found in the hepatic cells themselves.

In all cases of nodular leprosy the testes atrophy and undergo fibrotic changes, bacilli and globi being found both in and around the tubules, free and in cells.

In all forms of leprosy the lymphatic glands appertaining to parts in which leprous deposit is present are characteristically affected. They are swollen and hard, and on section the gland tissue is seen to have a yellowish tinge from an infiltration which contains numerous bacilli and globi.

Albuminoid disease of the alimentary canal, liver, and spleen, and nephritis occur in a large proportion of the cases of nodular leprosy.

Diagnosis.—The touchstone in all doubtful cases is the presence or absence of anæsthesia in some skin lesion, or in some skin area. Anæsthesia is rarely

absent in leprosy; generally, in the implicated spots it is complete, or nearly so. It should be particularly sought for towards the centre of maculæ, in the pale patches left after the fading of former maculæ, in the hands and feet, and in nodules of some standing. In no other skin disease is definite anæsthesia a symptom.

Vitiligo or leucodermia—sometimes called white leprosy, and by the vulgar very generally regarded as true leprosy—bears a certain resemblance to the pale post-macular patches referred to; not to mention other features, the absence of anæsthesia in leucodermia at once settles diagnosis.

Further assistance may sometimes be got in doubtful cases from the fact that leprous spots rarely perspire. A hypodermic injection of pilocarpine is of use in bringing out this point.

The sensory and trophic lesions of syringomyelia might be mistaken for nerve leprosy, but the general history of the case, the history or presence in leprosy of macular eruption, of thickened nerve trunks, and of enlarged lymphatic glands, and their absence in syringomyelia, are mostly sufficient to establish a diagnosis.

The occurrence of an acid-fast bacillus in the sputum of a patient coming from a country in which leprosy is common should be regarded with suspicion, and its true nature tested by injection of the sputum into the guineapig.

It is hardly necessary to point out the diagnostic marks of leprosy as against syphilis,* erythema multiforme, erythema nodosum, trypanosomiasis, lupus vulgaris, lupus erythematosus, psoriasis, eczema, lichen planus, cheloid, body-ringworm, erythrasma, pityriasis versicolor, pellagra, elephantiasis arabum, etc. Mistakes can scarcely be made unless from carelessness, or by someone completely ignorant of the nature, history, and symptoms of these diseases.

In approaching the diagnosis of skin eruptions, localized pareses, muscular atrophies, and anæsthesia in patients living in or coming from a country in

* Unfortunately the Wassermann reaction is of little value, as the majority of leprous sera are said to give a positive result

which leprosy is endemic, the possibility of their being attributable to this disease must be borne in mind. If doubt exist, and it be found feasible, search for the bacillus should be made in eruptions, or in thickened nerves, or in any nasal or other morbid discharge that may be present. If this be found the diagnosis of leprosy will be infallibly established.

Prognosis.—Complete recovery is an event so rare in leprosy that, though it may be hoped for, it must not be expected. Recovery from the actual disease itself—that is, in the sense that fresh leprous infiltration may cease to occur, and old infiltration may be absorbed, and that the bacilli may die out—is perhaps the rule in nerve leprosy; but the effects of the leprous process are generally permanent, the trophic lesions resulting from nerve destruction being irremediable. Such cases may live, however, for many years—thirty or forty—and die of some other disease.

Nodular leprosy is usually a much more acute disease than nerve leprosy, sapping the strength and general health much more effectually and more quickly. It rarely runs its full course, death being brought about by some intercurrent disease, such as, and especially, phthisis, nephritis, albuminoid degeneration of the alimentary tract, dysentery, stenosis of the larynx, or pneumonia. It may even prove fatal as a sort of "galloping" leprosy within a year of its first declaring itself.

Etiology. *Age.*—It is open to question if leprosy has ever been seen in the fœtus. It has once or twice been reported in the newly born. Cases are also on record of its occurrence as early as the first and second years of life; such cases, however, are quite exceptional. Leprosy is extremely rare before the fifth or sixth year. In the great majority of instances the disease begins between the tenth and thirtieth year. It rarely commences after 40, although it has been known to begin up to and even after 70.

Sex; occupation; social and hygienic conditions.—Apart from social conditions as affording opportunity for contagion, sex seems to have little bearing on the liability to leprosy. The same

may be said of occupation, and social and hygienic conditions in general. Very probably bad food and bad hygienic circumstances have in this, as in most germ diseases, a predisposing influence; but they certainly cannot create a lepra bacillus and leprosy, any more than they can create an acarus and itch. This is abundantly shown by the absence of leprosy at an earlier period in countries in which, without alteration in the food or other hygienic conditions, the susceptibility of the natives to the disease was subsequently proved by its rapid spread on being introduced from without, e.g. the Sandwich Islands and New Caledonia; and also by the disappearance of the disease, in other instances, under the influence of the segregation and isolation of lepers, without any concurrent material alteration in food or other circumstances, e.g. Scotland, Ireland, and most European countries.

Sir Jonathan Hutchinson very sagaciously and truly remarks that leprosy is more especially a disease of semi-civilization. Savages are exempt; the highly civilized are exempt; but when the savage begins to wear clothes and live in houses he becomes subject to the disease. In other words, in the early stages of civilization opportunities of infection are multiplied, and their influence is not counteracted by cleanliness of house or person.

Climate.—Climate can in no way be considered a cause of leprosy, for leprosy exists in all climates and in all latitudes. But it does seem to have some influence in determining, to a certain extent, the type the disease assumes. It would appear that the nodular form is more common in cold, damp climates; the nerve form in warm or dry climates.

The lepra bacillus.—Hansen remarks, "There is hardly anything on earth, or between it and heaven, which has not been regarded as the cause of leprosy." However true this remark may be as regards times prior to Hansen's discovery, we are now practically certain that the lepra bacillus is the cause of leprosy. The only gap in the evidence, otherwise conclusive, lies in our present inability to convey with certainty,

by inoculation or otherwise, the cultivated bacillus to the lower animals, or, perhaps, to man himself.

Many attempts have been made to communicate leprosy to man by inoculation; hitherto, with one questionable exception, all have failed. A Sandwich Islander, apparently at the time free from leprosy, was inoculated from a lepra nodule. Within a month he had symptoms of leprous neuritis; two years later he was a confirmed leper; and in six years from the date of the inoculation he died of leprosy. Unfortunately the subject of the experiment was a native of a country in which leprosy was extensively endemic, and, besides, he had lived among lepers; in fact, members of his family were lepers. However possible it may be that the bacillus in this instance had been communicated by the inoculation, the circumstances in which the experiment was made, and the unusual shortness of the incubation period, are against its being regarded as conclusive evidence of the inoculability of the disease.

To bridge over this important gap in the evidence, we have to fall back on the close analogy that subsists between *Bacillus lepræ* and *Bacillus tuberculosis*, the leproma and the tubercle, leprosy and tuberculosis. In consideration of this and other circumstances, it is generally conceded that *Bacillus lepræ* is the cause of leprosy, just as *Bacillus tuberculosis* is the cause of tubercle. Authorities differ, however, as to the way in which the bacillus is acquired.

How acquired.—It is absurd to suppose that an organism, no matter how humble its place in the scale of life, can originate *de novo*. Disregarding this, we have to consider two principal views as to the way in which the bacillus is acquired—heredity and contagion.

Heredity.—From the fact that it tends to run in families * and that in certain instances it assumes the appearance of atavism, leprosy, until the *Bacillus lepræ* was discovered, was almost

* It has been estimated that 10 per cent. of the children of leprous parents, provided the children remain under the local conditions in which the parents lived, become lepers; if the parents emigrate to a non-endemic country before the birth of the children, this liability ceases.

universally—as it still is by some—believed to be an hereditary disease. That this belief, in the same sense as that tubercle may be said to be hereditary, was well founded is quite possible; that is to say, that certain physio-pathological qualities predisposing to leprosy may be inherited. But since the discovery of the bacillus it is impossible any longer, if we properly consider it, to believe that the bacillus itself, and therefore the disease it causes, can be hereditary in the scientific sense of the word. Physiological peculiarities and susceptibilities may, but parasites cannot, be inherited. It is true the ovum may be infected by a germ, as in syphilis; but infection is not heredity. That the ovum can be infected at some stage of its existence by the lepra bacillus is proved if it be true that children have been born with the lesions of leprosy on them. But the fact that leprosy is common in the descendants and blood collaterals of lepers is no proof of ovum infection in every, or perhaps in any case; for family liability is quite as explicable by an hypothesis of contagion, or outside infection, as by an hypothesis of inherited infection. Not only may the individuals of a family inherit a family predisposition of susceptibility to the bacillus, but, as a family, the members of it are generally at one time or another closely associated, exposed to the same hygienic influences, liable by contact to communicate each other's parasites, or to acquire the parasites latent in their common surroundings. Because the members of a family simultaneously, or one after another, contract scabies, or ringworm, or typhoid, no one supposes on that account that any of these diseases is hereditary.

Without absolutely denying the possibility of ovum infection, the probability is that such an event is very rare. The age at which leprosy usually appears is against such a supposition. The latency of a germ for twenty, thirty, forty, or even seventy years is an extremely improbable thing and without parallel in pathology. Atavism, or rather, the appearance of atavism, frequently met with in leprosy, is also against such a supposition; for, although we can understand infection of an ovum by a leper parent, we cannot understand the transmission of a germ from a grandparent to a grandchild through a parent who is not, never was, and may never become a leper. Such a thing would imply proliferation of the bacillus in the parent without pathological evidence of its presence.

Even admitting that leprosy is sometimes transmitted by ovum infection, this method of transmission cannot be the only one, or even a common one, for many lepers have no leper ancestors; and, as is well known, the healthy European, coming from a country in which leprosy has not been seen for generations, may acquire leprosy on visiting a country in which the disease is endemic.

If leprosy be communicated generally, or even sometimes, by parent to child by heredity, how explain the striking fact, brought out by Hansen, that of the numerous offspring of 160

Norwegian lepers who emigrated to America not one has become a leper?—or, again, the equally well attested fact that children sometimes become lepers first, their parents afterwards?

Another powerful argument against the doctrine of heredity is the circumstance that lepers become sterile early in the disease. From this it is evident that unless the ranks of leprosy are recruited in some other way than by heredity the disease would inevitably die out in one, or at most two generations.

From considerations such as these the view that leprosy is an hereditary disease has now few adherents among the well informed.

Contagion.—With few exceptions, the best authorities believe that leprosy is propagated by contagion, and only by contagion. The same unanimity of opinion does not obtain as to the particular way in which, or medium by which, the contagium is applied; but that it passes, directly or indirectly, from the infecting leper to the infected, nearly all are agreed to regard as being practically proved. The principal facts and considerations on which this important conclusion is founded are as follows:—

Leprosy is a germ disease, and therefore it cannot originate *de novo*. It must come from a pre-existing germ whose habitat may be air, soil, water, plant, beast, food, or man. That the habitat of the infecting germ is man is rendered in the highest degree probable by the fact that the germ is found in the human tissues and, hitherto, nowhere else; and by the fact that leprosy has never been known to appear on virgin soil independently of the prior advent of a leper. When a leper settles down in virgin country, after a time cases of the disease crop up among his companions and immediate neighbours. Some of these newly-made lepers, proceeding to a different part of the country, in time become centres for other groups of cases. Thus in the early history of the introduction of leprosy into a virgin country—as New Caledonia—the spread of the disease from individual to individual, and from place to place, can be, and has been, traced.

In further proof it can be advanced that not only may a native of a non-leper country acquire the disease on visiting a leper country, but he may also communicate the disease to others, his countrymen,

on his return to his own country. There is at least one well-authenticated example of this on record. Dr. Hawtrey Benson, in 1872, showed at the Medical Society of Dublin a leper, an Irishman, who had acquired his disease in the West Indies. After his return to Ireland he slept in the same bed as his brother, who, moreover, sometimes wore the leper's clothes. In time the brother, who had never been out of the United Kingdom, became a leper, and was shown to the same medical society in 1877. In this case there can be no question of fact or of diagnosis. Such a case can only be explained by contagion. Though not quite so well authenticated and conclusive, many similar instances of the communication of leprosy by contagion are on record. The case just mentioned is alone almost conclusive; for if leprosy is proved to be communicable by contagion in one case, the probabilities are that it is so acquired in every case.

It has been advanced against the contagiousness of leprosy, that it attacks a very small proportion only of the attendants, nurses, and doctors in leper asylums. But might not a similar objection be raised to the contagiousness of scabies or of ringworm? The conditions for successful contagion are known and can be easily avoided in the latter diseases; they are not known, and are therefore not invariably avoided in leprosy. All contagious diseases demand certain conditions for their diffusion. In some diseases these conditions are easily complied with and often concur; in other diseases they are with difficulty complied with and rarely concur. Leprosy belongs to the latter category.

Probably intimate personal contact, and certain concurrences in the phases of the disease with special conditions in the health or physiological state of the recipient, are necessary for the successful communication and acquisition of leprosy. The simple implantation of the bacillus does not suffice; for, as already pointed out, of the many inoculations that have been made only one has any claim to be regarded as having been successful.

of treatment now coming into vogue for tuberculosis are equally applicable to leprosy.

Many drugs have been regarded, from time to time, as being more or less in the nature of specifics in the treatment of this disease. But, though some of these drugs appear for a time to do good, and in consequence acquire a certain degree of popularity, hitherto all of them, one after another, have sooner or later fallen into disfavour. One is very apt to be deceived in estimating the value of a drug in leprosy. The leper applies for treatment generally during, or soon after, one of the periodical exacerbations of the disease, and when the nodules and other eruptions are active and well pronounced. In the natural course. of events, and without treatment of any description, especially if the patient be placed under favourable hygienic conditions, these acute manifestations tend to become quiescent, and the disease temporarily to ameliorate. Observers are too apt to attribute this natural and temporary amelioration to whatever drug the patient may happen to be given at the time. Moreover, in judging of the value of any drug in leprosy, it must be remembered that the disease may be arrested spontaneously, or even be recovered from, without the use of any drug whatever.

Chaulmoogra oil (*Oleum gynocardium*), in doses of from 2 to 10 up to 40 drops or more, according to tolerance, three times a day, together with inunction of the same drug mixed with some oil, is a favourite remedy with English practitioners. Such lepers as can assimilate large doses of this drug appear to derive benefit. Sandwith has reported a case in which marked benefit followed persistent hypodermic administration of chaulmoogra. I have had lepers under my care who, in addition to large doses of chaulmoogra by the mouth, received hypodermic injections daily up to one drachm of the drug. The improvement for a time was marked. The bacilli, however, were just as abundant in the nodules during and after as before treatment, and there was no alteration in their appearance.

Encouraged by the clinical results, I have persevered with this treatment for many weeks at a time. In one instance the patient died from what was suspiciously like fat embolism; in another, while very large doses of chaulmoogra were being taken by the mouth and injected hypodermically, severe leprotic fever, associated with profuse eruption of lepromata, set in.

Anti-leprol (Bayer), a preparation derived from chaulmoogra oil, is better tolerated than the crude drug and may be given in larger doses, up to 2 or 3 drachms a day by mouth and 7 minims subcutaneously twice a day.

Rocamora reports favourably of combining a prolonged (eighteen months) salvarsan treatment with a chaulmoogra course.

Gurjun oil, once in favour, seems to have been abandoned.

Unna claims to have cured several cases of leprosy by the internal administration of ichthyol in increasing doses, combining the internal medication with vigorous rubbing of the arms and legs twice a day with pyrogallic acid (10 per cent.) in lanolin, and the cheeks and trunk with chrysophanic acid (10 per cent.) in lanolin; at the same time applying to the forehead and chin a plaster of chrysophanic and salicylic acids with creosote, changing the plaster every day. The treatment is continued for a month, and is then followed by a course of warm baths before being resumed.

Tuberculin has also been tried. It produces a local and a general reaction, which is sometimes curiously delayed for one or two days. So far from doing good it seems to aggravate the disease, causing fresh eruptions, and also causing bacilli to appear in the blood.

Radcliffe-Crocker recorded several cases of leprosy in which great improvement followed weekly hypodermic injections of $\frac{1}{5}$ gr. of perchloride of mercury.

Iodide of potassium aggravates leprosy if given in full doses; it not only affects the general health prejudicially, but it causes fresh eruptions to appear.

Danielssen regards salicylate of soda, combined with cod-liver oil, quinine and iron, good food, and good hygiene, as the best treatment for leprosy. He claims for the salicylate, if commenced within the first few months from the appearance of the disease, that it sometimes effects a cure. He begins with 15 gr. four times a day, and gradually increases the dose during six months or a year.

I have tried thyroidin in a case of nerve leprosy. The patient is now absolutely free from symptoms.

Salvarsan administered at frequent intervals intravenously and combined with anti-leprol is said to have given favourable results in nodular, but not in anæsthetic cases.

Hydroxylamin, europhen, naphthol, salol, methylene blue, and aristol have also been tried recently the results have not proved encouraging.

It has been proposed to treat leprosy by inoculations of the erysipelas streptococcus, or by injections of the filtered toxin obtained from cultures of that organism (Impey).

Nerve-stretching, with or without nerve-splitting, has been strongly advocated (MacLeod) for the cure of leprous neuralgia, anæsthesia, muscular atrophy, and other trophic lesions. At the best they can benefit the local lesion alone, and that but temporarily, and only in the earlier stages of the leprous neuritis before the nerve has undergone fibrous transformation.

In the case of leprous nodules spreading on to the cornea and threatening to interfere with the line of vision, Brockmann has shown that the extension of the leproma may be arrested by division of the cornea on the pupillary side of the lesion; it is found that the bacilli do not traverse the cicatrix. Tarsorrhaphy for ectropion of the lower lid; iridectomy for iritis, or synechiæ; tracheotomy for laryngeal stenosis; and necrotomy for bone disease, may sometimes have to be performed. Horder strongly recommends amputation for perforating or other forms of ulceration; the general health is much improved by the removal of such sources of sepsis. The existence of leprosy

does not materially interfere with the success of surgical operations. I once removed an enormous elephantiasis of the scrotum from a confirmed leper; the presence of the leprosy did not prevent sound healing of the extensive operation wound, the man making a good recovery so far as the operation was concerned.

If only one tubercle or one limited lepra macula is present, and there have been no constitutional signs of a general invasion, it is advisable to excise freely the affected spot.

What promised at one time to prove an important advance in the therapeutics of leprosy is the method introduced by Prof. Deycke under the name of *nastin* treatment.

Prof. Deycke obtained from a case of nodular leprosy a peculiar acid-fast bacterium—*Streptothrix leproïdes*—resembling in many respects *Bacillus lepræ*, but differing from the latter inasmuch as it could be readily cultivated. In unskimmed milk it forms a brilliant orange-red pellicle, which on digestion with ether yields a fatty substance—"nastin"—of definite chemical character. Injections of pure nastin in oily solution give rise in some lepers to inflammatory reaction of varying degrees of intensity—it may be violent; in other lepers again no such reaction occurs. Concurrently with reaction there is pronounced bacteriolysis and disappearance of the lepra bacilli as evidenced by their losing their staining reactions and by their disintegration. Several patients treated in this way improved, some apparently recovering; but the uncertainty as to whether in any given case reaction might not prove of so violent a character as to be dangerous to life imposed limitations upon the general use of the remedy.

Finding that benzoyl-chloride ($C_6H_5.CO.Cl$), by removing their fatty protective contents, rapidly deprived tubercle bacilli of their "acid-fastness," he concluded that this substance might act similarly on the lepra bacillus; and also finding that benzoyl-chloride was innocuous, he concluded that by combining it with nastin the therapeutic efficiency of the

latter might be so reinforced that it could be used in doses so small that violent reaction would be avoided. Experiment justified the conjecture, and although benzoyl-chloride administered alone has no therapeutic action in leprosy, given in appropriate combination with nastin, in a large proportion of instances, although not in all, the results are highly satisfactory, the lepra bacilli and lepra lesions slowly or more rapidly disappearing.

Prof. Deycke's hypothesis as to the mode of action of the combination is to the effect that the nastin element, having affinities with the fat of the lepra bacillus, acts merely as the introducer of the benzoyl-chloride, which is the actual bactericide.

As the result of much experience Prof. Deycke considers that what he calls "Nastin B^1," in which one part of nastin is dissolved in forty parts of benzoyl-chloride, and this again in sterile olive oil, is the best combination, rarely, if properly administered, giving rise to reaction. A weaker solution, "Nastin B^0," he uses in cases of ophthalmic and nerve leprosy, as a special precaution against dangerous reaction. After the weaker preparations have been used for some time a stronger nastin, B^2, may be employed.

There are certain points in the nastin treatment of leprosy on which Prof. Deycke lays stress: (1) Reaction from excessive doses is unnecessary and should be avoided. (2) Not too frequent injections; once a week suffices. (3) Perseverance for months and years, intermitting the injections for a month or two occasionally.

Reports from British Guiana, where systematic trial of this treatment on a large scale has recently been carried out, speak favourably of the results up to the first six months, but subsequently the disease ran its usual course and further trial of a promising therapeutic agent was abandoned. Other and similar "vaccines," such as Beauchamp-Williams's and Rost's "leproline," are on their trial.*

* Nastin preparations may be obtained from Messrs. A. & M. Zimmermann, 3, Lloyd's Avenue, London, E.C.

CHAPTER XXXVII

YAWS (FRAMBŒSIA)

Definition.—Yaws is a contagious inoculable disease characterized by an indefinite incubation period followed usually by fever, by rheumatic-like pains, and by the appearance of papules which generally develop into a fungating, encrusted, granulomatous eruption. It runs a chronic course; is mostly protective against a second attack; is believed to be caused by *Treponema pertenue;* is amenable to salvarsan, and, to a certain extent, is influenced by mercury and potassium iodide.

Geographical distribution.—Yaws is widely diffused throughout the greater part of the tropical world. In certain places it is very common—as in tropical Africa, particularly on the west coast; in many of the West India islands; in Ceylon, where it is one of perhaps several diseases included under the term *parangi;* in Fiji, where it is known as *coko;* in Java; in Samoa; and in many of the islands of the Pacific. It is difficult to say to what extent it exists in India; some deny its presence there altogether, but recent observations show that it does occur there to a limited extent; Powell has recognized and described it as occurring in Assam. Barker and Gimlette have shown that the skin disease described by Brown under the name of *purru*, and common in parts of the Malay peninsula, is yaws. Yaws occurs in China, but is rare there—at all events on the coast. In some of the West India islands, and Fiji, almost every child passes through an attack. In the latter, according to Daniels, those children who do not acquire the disease in the ordinary way are inoculated with it by their parents, who regard an attack of yaws as an occurrence more or less necessary and wholesome. Nicholls has made a

careful and admirable study of West Indian yaws. His inclination is to look upon parangi, coko, and similar Asiatic and Pacific island diseases as specifically different from the African and West Indian disease. Daniels, however—a most accurate observer, who has had extensive experience in Fiji, in British Guiana, and in Africa—shows very clearly that in these places the diseases are identical. Probably the view that certain forms of the parangi of Ceylon are not yaws is likewise incorrect.

It is impossible at the present day to settle the point, but it seems probable that yaws was originally an African disease, and, so far as America and the West Indies are concerned, that it was introduced by negro slaves. In the days of West Indian slavery the specific and infectious nature of yaws was thoroughly recognized. The planters, from economic, apart from other considerations, by instituting yaws-houses and similar repressive measures, took much trouble to keep the disease under. Since emancipation has permitted the West Indian negro to revert to some extent to the state of savagery from which he had partly emerged, yaws has again become very prevalent, and is now a principal and loathsome feature in the morbidity of these islands. Yaws is practically confined to the tropics and subtropics, and even there is absent at high altitudes.

Etiology. *Contagion and heredity.*—As yaws is highly contagious, all circumstances favouring contact with the subjects of the disease favour its occurrence. Simple skin contact does not suffice; a breach of surface is necessary. Probably the virus is often conveyed by insect bites, or by insects acting as go-betweens and carrying it from a yaws sore to an ordinary abrasion, wound, or ulcer. Thus the disease often commences in a pre-existing ulcer. Cases are prone to originate in certain dirty houses, the virus from previous yaws patients seemingly impregnating the floors and walls of the filthy huts in which the latter had resided. In this way the disease may be acquired without direct transference from an existing case.

Yaws is neither hereditary nor congenital. A pregnant mother suffering from yaws does not give birth to a child suffering from the same disease, nor one which will subsequently develop yaws unless the virus be first introduced directly through a breach of surface after birth. It is not conveyed by the milk; nor does a suckling suffering from yaws necessarily infect its nurse.

Age, sex, occupation, race.—Although two-thirds of the cases in the West Indies occur before puberty, no age is exempt. Three males are infected to every female attacked. Occupation has no manifest influence. In the West Indies Europeans, Chinese, and Indians catch the disease if exposed to the contagium.

The virus.—Both Pierez and Nicholls found a micrococcus in yaws tissue and in the exudation. Cultures of this micro-organism introduced into certain animals did not give rise to the disease.

In 1905, by overstaining with Leishman's and Giemsa's stains, Castellani demonstrated in scrapings of yaws tissues the presence of an extremely delicate treponema, *Treponema pertenue* (*Spirochæta pertenuis*, *S. pallidula*), very like the spirochæte of syphilis. Castellani's observations have been amply confirmed.

To demonstrate the treponema, slides should be prepared from scrapings of an incised yaw papule before it has ruptured. The dried films are then overstained by Giemsa's or Leishman's method. The Burri or indian-ink method (*see* p. 226) provides a rapid and convenient means of demonstrating the spirochætes as thin wavy lines on a dark background. They can only be seen in a living state by the dark-ground illumination method. A fully developed yaw is unsuitable, because, in consequence of its having been exposed to external sources of contamination, a variety of organisms will be present and may confuse the observer. Opinions differ with regard to the dimensions, presence or absence of flagella and undulating membrane, and other minute details; suffice it to say that *T. pertenue* to the ordinary observer is morphologically indistinguishable from the corresponding germ of syphilis. Ranken, using

dark-ground illumination, has observed the extrusion of minute refractile granules which, after a brief interval, exhibit active rotary movements and which may constitute a stage in the evolution of the parasite. *T. pertenue* has been found in the spleen, lymphatic glands, and bone marrow, and, doubtless, it occurs in the blood. It is inoculable into monkeys and rabbits; in the former, especially in the ourang-outang, it gives rise to lesions similar to those in man.

Cultivation of *T. pertenue* has been successfully performed by Noguchi in ascitic fluid containing a piece of fresh animal tissue such as the kidney, the whole being covered with a layer of sterile paraffin. This rather complicated technique has been simplified by the later work of Hata, who substituted horse-serum in which the inoculation is made through the upper solidified layer. The organisms develop anaerobically in the lower fluid layers. To succeed in the cultivation of the pathogenic spirochætes strict anaerobiosis is necessary.

Symptoms. *The initial fever.*—In yaws there is an incubation stage of very variable duration—two weeks to six months*—the appearance of the characteristic eruptions being preceded by a certain amount of constitutional disturbance. The intensity of the general symptoms varies within wide limits. Sometimes they are hardly perceptible, and are not complained of; usually there is well-marked malaise with rheumatic pains. Occasionally there is severe constitutional disturbance, lasting for about a week, with rigor, smart fever—100° to 103° F.—persistent headache, pains—worse at night—in the long bones, joints, and loins, and sometimes gastric disturbance and diarrhœa. During the decline of these constitutional symptoms the eruption appears.

Stage of furfuraceous desquamation.—The skin becomes harsh and dry, loses its natural gloss, and here and there patches of light-coloured, very fine furfuraceous desquamation, best appreciated with the aid of a lens, are formed. These patches are mostly

* Paulet, who inoculated 14 healthy persons with yaws, found the first lesion in from twelve to twenty days; Charlouis, in 28 inoculations, observed a papule at the site of inoculation after fourteen days. Naturally-acquired yaws is reputed to have a longer incubation period than the inoculated disease.

small and circular; occasionally they are oval, irregular, or form rings encircling islets of healthy skin. Their extent and number are very uncertain. They are scattered irregularly over limbs and trunk; occasionally they may be almost confluent, the patches coalescing and giving rise to an appearance as if the entire skin had been dusted over with flour. On the other hand, this furfuraceous desquamation may be so slight as to be overlooked. In other instances it may be very marked, the heaping up of desquamating

TERZI.—

Fig. 89.—Case of yaws. (*Journal of Tropical Medicine.*)

epidermic scales producing white marks, very evident on the dark skin of a negro or Oriental.

This patchy, furfuraceous condition of the skin* not only occurs at the early stages of yaws, but may persist throughout the attack, or reappear as a fresh eruption at any period of the disease.

The yaw (Figs. 89, 90).—When the furfuraceous patches have been in existence for a few days, minute papules appear in them. Describing these papules,

* The furfuraceous eruption has been carefully studied by Nicholls. It is not mentioned by the majority of authors.

Nicholls remarks that, in examining them with a lens, "they are seen to be apparently pushed up from the rete Malpighii through the horny epidermis, which breaks over their summits and splits in radiating lines from the centre, the necrosed segments curling away from the increasing papule. When

Fig. 90.—Another case of yaws.

the papules become about a millimetre in height and breadth, a yellow point may be observed on the summits . . . consisting not of a drop of pus under the epidermis . . . but of a naked, cheesy-looking substance, which cannot be wiped away unless undue force be used. Frequently a hair will be observed issuing from this yellow substance, thereby indicating that the hair-follicles are the centres of the change

going on." This papular eruption may persist during the entire attack, or it may appear at any time during the course of the disease. When extensive and occurring late, it indicates a protracted attack.

The papule, having arrived at this stage, may either cease to grow, the apex becoming depressed, cupped, and lined with the yellow cheesy material alluded to; or it may go on, increasing in size, to the formation of the typical yaw. In the latter case the lesion gradually grows into a rounded excrescence, the yellow material at the top widening out so as to form a complete cap encrusting the little tumour. The yaw so formed may be no larger than a split pea; or it may attain the breadth of a crown piece. The smaller tumours are hemispherical; the larger are more flattened or even depressed at the centre, possessing everted, somewhat overhanging, rounded edges. Occasionally, though rarely, a big yaw may include an area of sound skin. Several yaws may coalesce, and together cover a large and irregular surface, as an entire cheek, a popliteal space, or the dorsum of a foot. In the case of these large yaws, the surface of the growth is apt to be irregular and fissured. The neighbourhood of the mouth and anus are favourite sites for coalescent yaws; in such situations the moisture of the parts softens and removes the crust wholly or in part, so that the surface, in addition to being fissured, may be more or less bare, sodden, and fungoid.

The crust which caps and encloses an uninjured yaw is yellowish, granular, blotched with blood-stains and encrusted dirt. At first the crust is somewhat moist, but gradually it becomes dry, brown, and even black. The crusts are firmly adherent, requiring some force to remove them; a proceeding which, though painless, may entail a little oozing of blood. Deprived of its crust the little swelling is seen to be red in colour, and generally smooth and rounded on the surface. According to size, it stands out anything from $\frac{1}{8}$ to $\frac{3}{8}$ in. above the surrounding healthy skin. Immediately after removal of the crust the exposed surface begins to pour out a pale, yellowish-

grey, viscid fluid which soon becomes inspissated, rapidly forming a fresh cap to the yaw. Pus, unless as a consequence of irritation, is not, as a rule, found under the crust.

Although the formation of the papules and yaws is attended with much itching, the yaw itself is not at all sensitive; the tumour may be touched, with acid even, without causing pain—a diagnostic point of some importance.

The yaw usually attains its maximum development in two weeks. For several weeks longer it remains stationary before beginning to shrink. The crust then thins, shrinks, darkens, separates at the periphery, and at last falls off, disclosing at the site of the former fungating mass a slightly thickened spot of fairly sound skin which, though pale at first, may subsequently become hyperpigmented.

Ulceration.—Such is the normal process of evolution and involution of a yaw. But it sometimes happens that the tumours, in place of becoming absorbed, break down and ulcerate, the ulceration, however, being confined to the yaw itself. In other instances ulceration goes deeper and extends circumferentially, giving rise to extensive sores with subsequent cicatricial contractions. Such ulcerations may or may not be encrusted. With the development of the deeper and wider forms of ulceration, the typical lesions of yaws may disappear for a time, or perhaps permanently. In the latter case the ulcers are said not to be infective, and do not communicate yaws; they are, therefore, to be regarded rather as complications or, it may be, sequelæ. Such ulcers may persist for years. Ulceration, according to Nicholls, occurs in about 8 per cent. of cases.

Onychia.—Yaws may occur around or under a nail and give rise to a troublesome form of onychia.

Foot yaws.—When a yaw develops on the sole of a foot, in consequence of being bound down by the dense and thick epidermis it causes much suffering. Spreading laterally under the thick, leathery, and unyielding epidermis, it may attain a large size. After a time the epidermis over the growth gives way,

splitting in a radiating fashion. Pressure being thus removed, the yaw fungates, and suffering diminishes.

A cracked, scaly condition of the hands and feet, sometimes persisting for years, is not unusual in negroes, and must not be confounded with yaws, although not infrequently the two conditions coexist.*

Distribution.—The yaws may be scattered over the whole body; or the crop may be limited to one or two growths; or they may be confined to a circumscribed region of the skin. They are commonest on exposed parts, on the anterior surface of the body, and on parts especially liable to injury, as the feet and legs. They are most frequently found on the lower extremities; rarely on the scalp, and still more rarely in the axillæ. They are hardly ever seen on mucous surfaces unless about the lips, around the angles of the mouth, and in the nostrils, where they often form clusters.

Duration and recurrences.—Yaws lasts for weeks, or months, or years, its duration depending on the general health, idiosyncrasy, hygienic conditions, and the treatment employed. Mild cases in healthy subjects finish in about six weeks. In other instances, especially in the debilitated, the disease runs on for months, successive crops of eruption being evolved. Sometimes these recurrences may stop short at the stage of desquamation, or at the papular stage, or

* In the course of time the West Indian negroes have adopted a peculiar jargon—a mixture of French, English, and Spanish—to designate the various manifestations of yaws. The scaly patches are known in some of the islands as "pian dartres," in Jamaica as "yaws cacca"; the papular stage of eruption as "pian gratelle"; when the papular eruption occurs as a late symptom it may be called "pian charaib," or "guinea-corn yaws." The developed yaw is sometimes known as "bouton pian." "Tubboes," "tubba," "crabs," "crappox," "crabes" are expressions applied to the painful manifestations on the soles of the feet. Forms of chronic dermatitis on hands and feet are called "dartres," "tubboe," "crabs," "dry tubboes," or where exudation goes on between cracks in soles or palms, "running crab yaws." A large persistent yaw, probably in many instances the seat of the original infection, is sometimes known as the "mother," or "grandmother," or "mama-pian"; smaller yaws as "daughter" or "granddaughter" yaws. Yaws which show themselves some time after the disease appears to have subsided are called "memba" (remember) yaws. Yaws coalescing in the form of a ring are called "ringworm" yaws.

they may proceed to the formation of typical yaws. The recurrences are usually preceded by feverishness, pains in the bones and joints; and the successive crops may either be limited and partial in their distribution, or they may be general. In Fiji, Daniels states, the average duration of an attack of yaws is about one year.

The general health.—Except during the initial fever, or during one of the recurring febrile relapses, the general health is not as a rule affected. Occasionally, however, there is debility and cachexia; or there may be enlargement and tenderness of the lymphatic glands. In other instances the rheumatic pains are a principal feature, and may be very severe.

Persistent yaws.—That yaws sometimes effects a permanent hold is shown by the persistency with which it occasionally continues to recur during many years. In such cases the lesion has always the characters of a true yaw, and cannot be regarded as a "secondary" or "tertiary" manifestation in the sense in which these terms are applied to the late lesions of syphilis.

Powell describes two cases, mother and child, in whom, concurrently, a uniform swelling of the proximal phalanges of both hands occurred during the third year of an attack of yaws. To the touch the bones gave the impression of being rarefied. The swellings yielded to mercury.

Question of a primary sore.—An interesting point in the symptomatology of yaws is the question of the occurrence of a primary sore, as in syphilis. Numa Rat says there is such a sore, but that it is usually overlooked. He describes it as a papule with a pale yellow material at its apex, which may remain a papule, or which, after seven days, may ulcerate and subsequently cicatrize. Other observers do not agree with this. They say that though yaws virus applied to a pre-existing ulcer may render it unhealthy-looking and cause it to fungate like an ordinary yaw, yet successful puncture inoculations, although they sometimes give rise to a yaw at the point of inoculation, do not by any means always produce a local lesion,

much less an ulcer. Formerly it was thought that the lower animals were not susceptible to yaws. Several observers, including Castellani, have now shown that monkeys, even of a low order, can be successfully inoculated. Rabbits are also susceptible to intra-testicular and subcutaneous inoculations (Nicholls and Castelli).

Sequelæ.—Mention is often made of nodes, of gummatous-like thickenings, and of punched-out, serpiginous and lupoid ulcerations in connection with yaws. Many authorities regard all such phenomena as being generally the results of an independent, though concurrent, syphilitic or tubercular infection.

On the other hand, the peculiar character of the periosteal thickenings; the sabre-like bending of the tibiæ as if from some process of rarefying osteitis often leading to spontaneous fracture; the similar distortions of the bones of the forearms; the chronic serpiginous ulcerations of the forearms and legs, which, subsequently cicatrizing, lead to constriction, and cause unsightly chronic œdematous swelling of the distal parts; the gumma-like lumps on arms and legs, and even on the lips; these morbid phenomena, often encountered in yaws countries, taken in conjunction with the nature of the parasitic cause of this disease, tend to the conclusion that these lesions are of the nature of tertiary sequelæ. (Figs. 91, 92.) The subject requires further observation and study.

Gangosa; destructive ulcerous rhino-pharyngitis (Leys).—This disease, which has been regarded by some as a sequel of yaws, generally commences as an ulcer on the soft palate. Slowly spreading, it may make a clean sweep of the hard palate, of the soft parts, cartilages and bones of the nose, sparing the upper lip, which is left as a bridge across a great chasm, the floor of which is formed by the intact tongue. The disease may be arrested spontaneously at any period of its progress and long before so extensive a mutilation as that described has been effected; but it is always a long-standing and chronic affair and may linger as an indolent ulceration for years. As a rule, the larynx is spared; but, although

phonation may be retained, articulation is seriously impaired.

This disease is very common in parts of the West

Fig. 91.—Tertiary yaws, showing sabre-like deformity of tibiæ, radius and ulna, and multiple cutaneous ulcerations. [Photo: P. H. Bahr.

Indies—Dominica for example (60 cases in a population of 2,000, Numa Rat), Guam, where it is known as gangosa (1·5 per cent. of the population, Leys), the Carolines, Fiji, British Guiana and, undoubtedly,

many other parts of the tropics. I believe I have seen the same condition in South China.

It occurs at any age from childhood to 80. Leys saw it in Guam in children of 3, 4 and 9 years respectively.

[Photo: P. H. Baker.

Fig. 92.—Tertiary yaws, showing tibial periosteal nodes, ulcers, and deformity of phalanges.

The lesion has been attributed to leprosy, tuberculosis, syphilis, and yaws. Against its being a leprous disease is the circumstance that it is not attended with any of the other phenomena of leprosy.

Against its being of a tuberculous nature is the circumstance that it is confined to the tropics. Against its being syphilis is the practical absence of syphilis among the natives of Fiji, where this form of ulceration is particularly common. Against its being a sequel of yaws is the want of correspondence in the proportional prevalence of the two diseases; for, although ulcerative rhino-pharyngitis is common in some places in which yaws is common, it is rare in other places where yaws is common, and common in other places where yaws is rare. For these and other reasons Leys has thrown out the suggestion that destructive rhino-pharyngitis of the tropics is an independent disease produced by a special micro-organism as yet undetected, and not, as has been supposed, a sequel of yaws. On the other hand, it may be a form of buccal leishmaniasis.

Mortality.—Although in the literature of the subject reference is made to deaths from yaws, yet, judging from the statistics collected by Nicholls, the mortality must be very small indeed. In 7,157 West Indian cases, treated in various yaws hospitals, there were only 185 deaths—a mortality of 25·8 per thousand; a death-rate, as Nicholls points out, less than the average annual death-rate in one of the islands —Antigua. Doubtless, although yaws itself seldom proves directly fatal, intercurrent diseases, such as sloughing phagedæna and phagedænic ulceration, predisposed to by the skin lesions, occasionally do so.

Morbid anatomy and pathology.—No visceral changes have been found peculiar to yaws, although, of course, when yaws concurs with syphilis, gummata, etc., may be found; in this case the concurrent gummata may belong to the syphilitic and not to the yaws infection. An important point of contrast in the respective morbid anatomy of yaws and syphilis is the absence of endarteritis in the former and its frequency in the latter.

The tumours on the skin are granulomata made up of round or spindle-shaped cells, held together by a small amount of connective tissue and abundant blood-vessels. The focus of the circumscribed cell

proliferation is the papilla, which becomes very much swollen, and the Malpighian layer.

Diagnosis.—A painless, insensitive, larger or smaller, circular, encrusted, red granulomatous excrescence occurring in the endemic district is almost certainly yaws. The most important point in connection with yaws, both as regards diagnosis and etiology, is its relationship to syphilis. It has been, and is still, held by some distinguished authorities —Hutchinson, for example—that yaws is syphilis modified by race and climate. Certain features which the two diseases have in common are pointed to, and, doubtless, the recent discoveries of a spirochæte in association with both diseases will be adduced in support of this contention. So far as clinical and microscopical evidence goes, it is decidedly in favour of, not to say conclusive for, regarding the two diseases as specifically distinct. There are many points of contrast in their clinical features. I may mention the primary sore, the infection of the fœtus, the adenitis, the exanthem, the alopecia, the absence of itching, the iritis, the affection of the permanent teeth, the bone and eye affections, the congenital lesions, the polymorphism of the eruptions, the nerve lesions and the gummata of syphilis. All these are wanting in yaws. Moreover, both diseases may concur in the same individual (Powell cites two cases, and Charlouis two, of syphilis supervening on yaws); and antecedent syphilis certainly does not confer immunity as against yaws, nor antecedent yaws against syphilis. The serum of both diseases gives a positive Wassermann reaction. Monkeys inoculated with yaws are not absolutely immunized against syphilis, but Prowazek found under experimental conditions that inoculation of the spirochæte of yaws conveys a relative immunity to a subsequent syphilitic infection, and that monkeys were less susceptible to syphilis after a previous attack of yaws. Yaws may die out in a community, as in British Guiana (Daniels), yet syphilis remain; yaws may be universal in a community, as in Fiji and Samoa, and yet true syphilis, whether as an acquired or a congenital

disease, be unknown. Finally, syphilis has never been shown to give rise to yaws, nor yaws to syphilis; neither, so far as known, has yaws been evolved in any community from syphilis, or appeared independently where the possibility of its having been introduced from a recognized yaws centre could be excluded with certainty.

The therapeutic argument for the identity of the two diseases is a very fallacious one. Sulphur will cure scabies and pityriasis versicolor; yet from this circumstance we may not conclude that these diseases are identical. The same may be said in respect of the influence of mercury and iodine on syphilis and on yaws.

Prophylaxis resolves itself into the adoption of measures to prevent contagion. These are: the isolation and segregation of the affected; the dressing and treatment of wounds in the hitherto unaffected; the application of antiseptic ointments to yaws sores, so as to obviate the diffusion of germs; the purifying or destruction by fire of houses or huts notoriously infected; the prevention of pollution of bathing water by yaws discharges.

Treatment.—All are agreed as to the propriety of endeavouring by good food, tonics, and occasional aperients to improve the general health. Most are agreed as to the propriety of endeavouring to procure a copious eruption by stimulating the functions of the skin by warm demulcent drinks; by a daily warm bath with plenty of soap; and, during the outcoming of the eruption, by such diaphoretics as liquor ammoniæ acetatis, guaiacum, etc. Confection of sulphur is also recommended as a suitable aperient; it may be taken frequently in the early stages of the disease. All are agreed as to the propriety of avoiding everything—such as chill—tending to repress the eruption; warm clothing is therefore indicated. Many use mercury, or potassium iodide, or both, after the eruption is fully developed. These drugs have undoubtedly the power of causing the eruption in yaws to resolve. Some practitioners rarely use them, or, if they use them, do so only at the latest

stages of the disease, considering that relapses are more prone to occur after their too early employment. Mercury, owing to its proneness to cause anæmia, is less frequently employed than potassium iodide. Where the eruption is persistently squamous, or papular, arsenic is frequently prescribed. Some touch the yaws with sulphate of copper; some apply nitrate of mercury ointment; others, iodoform ointment; others leave them alone, confining their local measures to the enforcement of cleanliness. When the soles of the feet are attacked, the feet ought to be soaked in warm water to soften the epidermis, which should then be cut away sufficiently to liberate the subjacent yaw. Ulceration must be treated on ordinary principles. During convalescence iron, arsenic, and quinine are indicated.

Except where much bone destruction has taken place salvarsan and, better, neo-salvarsan have a rapid and remarkable curative effect in yaws in every stage of the disease. They are now the recognized specific treatment, and may be given intravenously or intramuscularly. The dose is 4 to 8 gr. for an adult male, proportionately less for females and children. The reader is referred to p. 238 for a description of the technique of administration. Alston has made the curious and interesting observation that the serum obtained from a blister applied to a yaws patient who has recently been treated with salvarsan acts, when injected subcutaneously into another yaws patient, as effectually as a dose of salvarsan.

The systematic use of salvarsan in a yaws community would, if thoroughly carried out, promptly get rid of the endemic, and, wherever possible, should be enforced.

CHAPTER XXXVIII

VERRUGA PERUANA

Definition.—A specific disease attended with a high mortality and characterized by fever, profound anæmia, and the development of yaws-like, fungating, prone-to-bleed granulomatous growths on the skin and mucous membranes.

Geographical distribution.—Between the 9th and 16th parallels of S. latitude, and at an elevation of from 3,000 to 10,000 feet, in certain narrow valleys of the western slopes of the Andes, an aggravated form of a peculiar disease, locally known as "verruga," is endemic.

The topical as well as the geographical range of verruga is singularly limited; it is confined to certain hot, narrow valleys or ravines, the inhabitants of neighbouring places being exempt. It is said that the disease may be acquired in merely journeying through the endemic districts, more especially if the traveller passes the night there.

Etiology.—Although out-of-door workers are most liable, all ages, classes, and both sexes, including infants, are liable to attack. In the endemic centres nearly everyone sooner or later gets the disease, and thus acquires a considerable though not absolute immunity.

The fatal experiment of Carrion, who inoculated himself with the virus from one of the characteristic sores, proved that the disease is communicable. Formerly it was believed that it attacked various domestic animals; this has been disproved. Recently monkeys have been successfully inoculated.

During the initial fever certain rod-like bodies are to be found in a large proportion of the red blood-corpuscles. They disappear when the eruption comes out, and are probably associated with or are an

effect of the rapid and extreme degree of blood destruction occurring at the early stage of the disease. A paratyphoid bacillus having pathogenic properties has been isolated at this stage; it, too, vanishes on the appearance of the eruption. Chlamydozoa-like bodies have recently been described as occurring in certain spindle cells in the verruga tumours.

The disease is most prevalent during the summer months when the streams are in flood, the air hot, still, and moist, when malaria is epidemic, and when insect life is abundant. An insect transmitter is suspected, but as yet not determined. Townsend, who has made special studies locally on this point, dismisses ticks, bugs, and the ordinary human ectozoa, and inclines to regard a species of phlebotomus as the carrier.

Pathology.—A remarkable feature of this disease is the rapidity and extreme degree of blood destruction. In bad cases the blood-count may drop in three or four days to 500,000 per c.mm., the picture being that of a pernicious anæmia. There is a marked polymorphonuclear leucocytosis with disappearance of eosinophiles; and during the later eruptive stage an eosinophilia with a mononuclear leucocytosis.

The granuloma begins as a neoplasm round the capillaries and resembles in its histology that of yaws (p. 652).

Symptoms.—The peculiar initial rheumatic-like pains and fever are apparently the same in character as those of yaws, only more severe, and, as in yaws, the constitutional symptoms subside on the appearance of the skin lesion—a granuloma macroscopically as well as microscopically identical with that of yaws. Just as in the latter disease, the eruption may be sparse or abundant, discrete or confluent. As in yaws, individual granulomata may fail to erupt; others may subside rapidly; others, again, may continue to increase, and then, after remaining stationary for a time, gradually wither, shrink, and drop off without leaving a scar. If difference there be in their clinical features between verruga and yaws, apparently it is more one of degree than of kind.

In verruga the initial fever may continue for weeks, or even for months. It is very severe in many instances. Often it exhibits features like those of a malarial infection, including intermittency, profound anæmia, and sometimes enlargement of the spleen and liver. Very probably in such cases it is the outcome of a double infection—verruga attacking a malarial subject. Not infrequently in the endemic district a certain type of fever, believed to be verruga fever, proves fatal before the appearance of definite skin manifestations such as would justify a positive diagnosis. This was apparently the case with Carrion. The symptoms in his case closely resembled those of the very deadly fever referred to, which is known locally as Oroya fever.

In addition to the severity of the fever and rheumatic pains, the Peruvian disease is remarkable for the tendency to spontaneous hæmorrhage exhibited by the skin lesions. Apparently this peculiarity is attributable, like the hæmorrhages in the affection known as "mountain fever," to the diminished atmospheric pressure at great altitudes; for when the patients descend to the lower valleys, or to the sea level, the tendency to bleeding ceases. Possibly the unusual vascularity of the swellings, which are sometimes permeated by a network of cavernous sinuses, also arises from the same circumstance.

In yaws we find no mention made of the occurrence of fungating granulomata in any situation but the skin. In verruga it would seem that the tumours may develop on mucous surfaces—in the œsophagus, the stomach, intestine, bladder, uterus, and vagina. Hence the dysphagia—a common symptom—and the occasional occurrence of hæmatemesis, melæna, hæmaturia, and bleeding from the vagina in this disease. Relapses both of the fever and of the eruption may occur.

Mortality.—The mortality ranges from 10 to 40 per cent. of those attacked. The risk is very much lessened on the appearance of the eruption.

Treatment.—Salvarsan seems to exert a specific influence, but its exact value has not been determined.

Cold, it is said, tends to repress the development of the eruption; until this appears fever and pain persist. For this reason, as well as to avoid the hæmorrhage from the lesions when they do erupt, the patients should quit the heights and descend to near the sea-level. External hæmorrhages, when they occur, must be treated by graduated pressure; otherwise, the local as well as the general treatment is the same as for yaws.

Where possible, workmen in endemic districts should quit the locality before sunset. On a certain railway running through the endemic zone on which the mortality from this disease was enormous, by Dr. Giana's advice the workmen were obliged to quit the locality before sunset; the case-incidence immediately diminished.

NOTE.—Since the foregoing was in type Strong has published (*New York Med. Journ.*, March, 1914) the results of his investigations on this disease in Peru. He comes to the conclusion that Oroya fever and verruga Peruana are two distinct diseases, the former produced by a special bacillus, the germ of the latter being still unknown. He succeeded in conveying verruga Peruana to monkeys.

CHAPTER XXXIX

ULCERATING GRANULOMA OF THE PUDENDA

Geographical distribution.—Neal, Ozzard, Conyers, and Daniels describe a peculiar form of ulcerating granuloma affecting more particularly the pudenda in dark-skinned races. Their observations were made in British Guiana, and principally on West Indian negroes. Daniels believes that he has seen a similar or the same disease in Fijians. The "serpiginous ulceration of the genitals" referred to by MacLeod, and recently by other writers in India, more especially by Maitland, is the same, or a similar disease, examples of which I can recollect having seen in South China. Taylor, of New York, has seen it in whites in the United States, Goldsmith has met with it in aboriginals in North Australia, and Renner in West African negroes. Doubtless, therefore, although hitherto little notice has been taken of this disease, it is widely distributed in the tropics.

Etiology.—There is reason for believing that the disease is generally, though not invariably, a venereal one. Maitland has seen it in the mouths of a husband and wife. He considers it may be inoculated on other forms of venereal sore, such as an ulcerating bubo, and that a compound sore may result. The nature of the virus has not been determined.

Spirochætes resembling *S. pallida* and *S. refringens* have been described by Wise as occurring in the ulcerations in British Guiana, but the nature of their relation to the disease has not been made out.

Donovan has described certain parasitic elements of undetermined nature, which he has demonstrated in scrapings from the deeper parts of the Madras form of these sores. The parasite (Fig. 93) is like a gigantic short bacillus with rounded ends, measuring

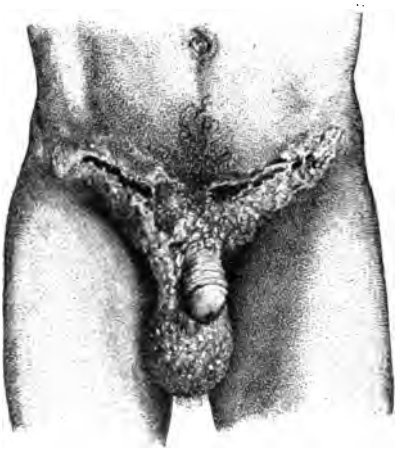
2 μ by 1 μ. It occurs in large mononuclear cells and in great profusion. The parasites are sometimes scattered irregularly through the protoplasm of the affected cells; more often they are arranged in little round clusters of eight or ten. On deep staining, something like an elongated nucleus can be made out. Donovan does not claim that in this body he has discovered the germ cause of ulcerating granuloma; but the position it occupies and its peculiar characters are highly suggestive. Flu has found similar bodies in six cases.

Fig. 93.—Parasitic elements in ulcerating granuloma of pudenda.

Age and sex.—Ulcerating granuloma has not been observed before puberty; it has been found only after 13 or 14, and up to 40 or 50. It occurs in both sexes, but particularly in women.

Symptoms.—The disease commences in the great majority of cases somewhere on the genitals, usually on the penis or labia minora, or on the groin, as an insignificant, circumscribed, nodular thickening and elevation of the skin. The affected area, which on the whole is elevated above the surrounding healthy skin, and is covered with a very delicate, pinkish, easily-rubbed-off epithelium,

excoriates readily, exposing a surface prone to bleed and break down, although rarely ulcerating deeply. The disease advances in two ways: by continuous eccentric peripheral extension, and by auto-infection of an opposing surface. In its extension it exhibits a predilection for warm and moist surfaces, particularly the folds between the scrotum and thighs, the labia, and the flexures of the thighs (Fig. 94). Its extension is very slow, years elapsing before it covers a



TERZI.

Fig. 94.—Ulcerating granuloma of pudenda in the male.

large area. Concurrently with peripheral extension a dense, contracting, uneven, readily-breaking-down scar forms on the surface travelled over by the coarsely or finely nodulated elevated new growth which constitutes the peripheral part of the diseased area. Occasionally islands of active disease spring up in this scar tissue; but it is at the margin of the implicated patch that the special features of the affection are best observed. In a case of some standing there is found a large area of white or irregularly pigmented, perhaps excoriated, unsound, contracting, folded and

dense cicatrix surrounded by a narrow, serpiginous, irregular border of nodulated, somewhat raised, red, glazed, delicately skinned or pinkish, superficially ulcerated or cracked new growth.

In the case of the female (Fig. 95) the disease may extend into the vagina, over the labia, and along the flexures of the thighs. In the male it may spread over the penis, involve the glans, scrotum, and upper part of the thighs. In either sex it may spread in the course of years to the pubes, over the perineum, and into the rectum, the recto-vaginal septum in

TERZI.

Fig. 95.—Ulcerating granuloma of pudenda in the female.

the female ultimately breaking down. At times a profuse watery discharge exudes and even drips from the surface of the new growth, soiling the clothes, soddening the skin, and emitting a peculiarly offensive odour. In this condition the disease, slowly extending, continues for years, giving rise to inconvenience and perhaps seriously implicating the urethra, vagina, or anus, but not otherwise materially impairing the health. The lymphatic glands do not become affected. The disease continues entirely local. Histologically this disease is allied to rhinoscleroma.

Histology.—On microscopical examination the new growth at the margins of the sore is found to be made up of nodules, or masses of nodules, consisting of round cells having large and, usually, badly-staining nuclei. These cells are embedded in a delicate fibrous reticulum. The nodular masses are, for the most part, covered by epithelium, their under surfaces merging gradually into a thick, dense fibrous stroma in which small clusters of similar round cells are here and there embedded. The growths, though very vascular, contain no hæmorrhages; and there are no signs of suppuration or of caseation, no giant cells, and no tubercle bacilli. In vertical section of the small nodules the round-cell mass will be found to be wedge-shaped, the base of the wedge being towards the skin; the deep-lying apex is usually pierced by a hair or two. The growth is found around sebaceous follicles, blood-vessels, lymphatics, and sudoriparous glands; but it is especially abundant, and most deeply situated, around the hair follicles.

Diagnosis.—Malignant and syphilitic ulcerations of the groin are common enough; the disease under notice, however, differs widely from these—clinically, histologically, and therapeutically. It is characterized by extreme chronicity—ten or more years; by absence of cachexia or of any tendency to cause death; by non-implication of the lymphatic system, and by non-amenability to mercury and iodide of potassium. The disease which it most resembles is lupus vulgaris. From this it differs inasmuch as it is practically confined to the pudendal region; affects mucous as well as cutaneous surfaces; tends to follow in its extension the folds of the skin; is not associated with the tubercle bacillus, giant cells, caseation, or other evidences of tuberculous disease.

Treatment.—This disease is very rebellious to treatment. Scraping and caustics, including the actual cautery, have been freely employed; but, although some improvement may be effected by these means, new nodules almost invariably spring up in the resulting cicatrix. Until recently complete excision, where practicable, offered the best chance of per-

manent cure; of course, such a proceeding had to be undertaken before large areas and important passages had become involved. Conyers and Daniels found that camphor and carbolic acid in equal parts, and salicylic acid in unguentum creasoti, 30 to 40 gr. to the ounce, gave the best results, although in no instance have they succeeded in effecting a complete cure, the growth invariably recurring in the scars soon after discontinuance of treatment. Maitland recommends the repeated application of Vienna paste followed by boric-acid poultices. Mercury and iodide of potassium are useless.

Judging from its relatively superficial nature and close resemblance to lupus, it seemed probable that ulcerating granuloma might prove amenable to some form of radiotherapy. This is actually the case, and X-rays are now regularly and successfully employed in Madras in the treatment of the disease. Of 37 cases treated in this way in Madras Hospital in 1908 all proved successful within an average period of two months. In three of the cases which could be followed up there was no recurrence four months after their discharge.

Section V.—ANIMAL PARASITES AND ASSOCIATED DISEASES

CHAPTER XL

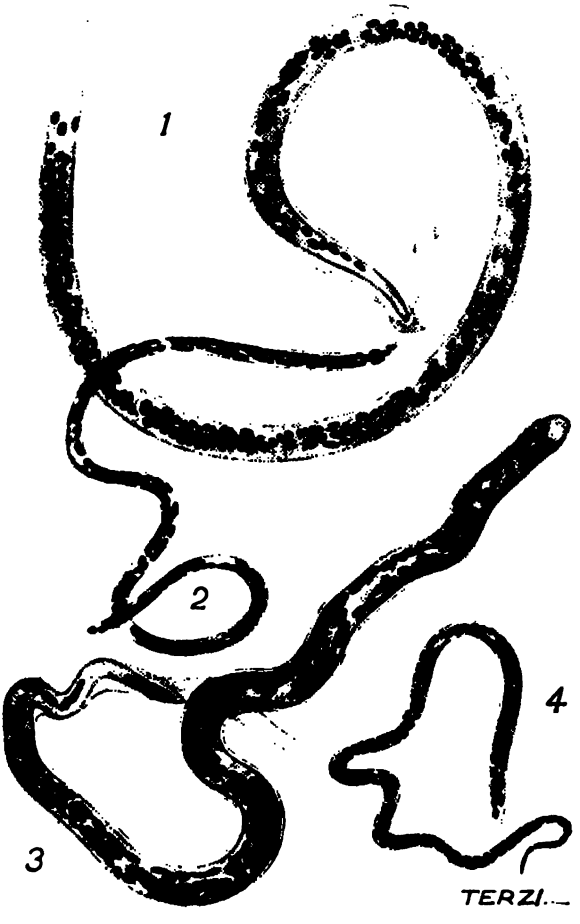
I. PARASITES OF THE CIRCULATORY AND LYMPHATIC SYSTEMS

FILARIASIS

History.—Our knowledge of this subject dates from the discovery by Demarquay, in 1863, of a larval nematode—*microfilaria bancrofti* (Plate X.)—in the milky fluid from a case of chylous dropsy of the tunica vaginalis. Later, in 1866, Wücherer found the same organism in the urine of a number of cases of chyluria. In 1870 Lewis made a similar observation in India, and in 1872 discovered that the blood of man was the normal habitat of this larval parasite, which he named, accordingly, *Filaria sanguinis hominis.* Four years later Bancroft, in Brisbane (Queensland), discovered the adult form, and Cobbold named it *Filaria bancrofti.* Since that time the subject has rapidly expanded, and its great practical importance in tropical pathology is now recognized.

Nomenclature of the parasites.—I have pointed out that Lewis's microfilaria* is not the only blood-worm in man, and that the human circulation is the habitat of the larvæ of no fewer than five, possibly of six or even more distinct species of filariæ. In consequence of this discovery, it was deemed advisable to modify the original name of Lewis's filaria. This I

* The term *microfilaria* has been suggested by Le Dantec to designate the larval forms of the various nematodes whose young circulate in the blood. I adopt it as being a convenient expression.



Microfilariæ of the blood.

1, Mf. bancrofti; 2, mf. perstans; 3, mf. loa; 4, mf. demarquaii.

PLATE X.

proposed to call *Filaria nocturna* ; but as, in accordance with the rules of zoological nomenclature, precedence must be given to the name previously suggested by Cobbold for the adult form, I propose to call the larval form *microfilaria bancrofti* (Fig. 96, *a*). The other filariæ of the blood I named *F. diurna*

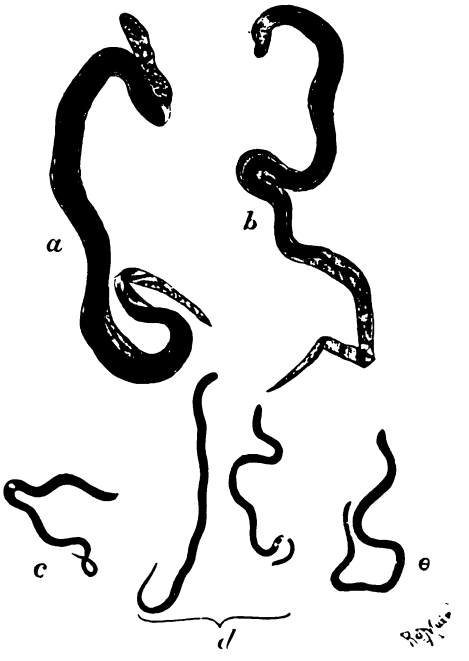


Fig. 96.—(*a*) Microfilaria bancrofti, × 300 ; (*b*) microfilaria loa, Africa, × 300 (*c*) microfilaria demarquaii, St. Vincent, × 300 ; (*d*) microfilaria ozzardi and microfilaria perstans, British Guiana, × 300 ; (*e*) microfilaria perstans, Africa, × 300.

(*mf. loa*), Fig. 96, *b* ; *F. demarquaii* (*mf. demarquaii*), Fig. 96, *c* ; *F. ozzardi* (*mf. ozzardi*), Fig. 96, *d* (a doubtful species) ; *F. perstans* (*mf. perstans*), Fig. 96, *e*; and *F. magalhães*, after its describer. (Plate X.)

Their pathological importance.—Only one of these parasites, so far as we know at present, appears to

have important pathological bearings—*Filaria bancrofti*, which, in its adult stage, inhabits the lymphatics of man. As regards the others, with the exception of *F. loa*, we have no knowledge of any serious pathological significance they may possess. There can be no question of the importance in tropical pathology of *F. bancrofti*; there is abundant reason to believe that it is the cause of endemic chyluria, of various forms of lymphatic varix, and of other obscure tropical diseases, including, probably, elephantiasis.

FILARIA BANCROFTI (Cobbold, 1877).

Synonyms.—*Filaria sanguinis hominis*; *F. nocturna*; *F. wuchereri*.

Geographical distribution and prevalence.—The geographical distribution of *Filaria bancrofti* is very extensive. It has been found as an indigenous parasite in almost every country throughout the tropical and sub-tropical world, as far north as Spain in Europe and Charleston in the United States of America, and as far south as Brisbane in Australia. In many places—South China, for example—quite 10 per cent., and in other places half of the population harbour it. I have ascertained that it is probable that one-third of the inhabitants of at least one district in India—Cochin—carry blood filariæ. I also find that in some of the South Sea Islands—Samoa, for example—fully one-half of the people are affected in this way. Thorpe has shown that in the Friendly Islands 32 per cent. of the people harbour this filaria. We have similar testimony as to the great frequency of the parasite in Madras from Maitland and others, in Demerara from Daniels, in several of the West India islands from Low, in West Africa from Annett, Dutton, and Prout. Doubtless, if diligently and systematically sought for, it could be found in most tropical countries.

Demonstration of blood microfilariæ.—Whoever would investigate the subject of filariasis will find that, in order practically to comprehend the subject and to provide himself with abundant material

for observation, it is advisable to make systematic examination of the blood of the inhabitants of some district in which filariasis is endemic. If this be done, the observer is sure to come across, sooner or later, cases in which *microfilaria bancrofti* abounds, and also of the diseases to which it gives rise.

Technique.—I recommend the following procedure as likely to supply the investigator not only with material, but also with much useful information. Let him visit, *late in the evening*, some hospital, or prison, or other establishment where he can have an opportunity of examining the inmates, and let him procure slides of the blood of, say, 100 individuals. The slides are conveniently prepared by pricking the finger of each person in turn, and transferring large drops of the blood so obtained to ordinary microscope slips by simply dabbing the centre of the slip on the blood. The blood is then spread out with a needle so as to cover in a moderately thin film about a square inch of one surface of each slip. Each slip, so soon as the blood is spread, should be laid on its uncharged surface on a smooth, level surface until dry; it is then labelled and put aside. One preparation of this description may be made from each person, who should be selected simply as a representative of the general population, and therefore irrespectively of his being physically sound, or of his being the subject of any particular type of disease.

The slides may be examined in various ways, either at once or, if more convenient, weeks or months afterwards; if kept dry and away from cockroaches, ants, etc., they do not spoil. A convenient plan is to dip the slides, without previous fixing, in a weak solution of fuchsin—about three or four drops or more of the saturated alcoholic solution to the ounce of water. They are left in the stain for about an hour, and then examined wet and without cover-glass. If the slides are old, they may stain too deeply; in this case they may be partially decolorized in weak acetic acid—two or three drops to the ounce of water—and afterwards washed. Recent slides, if placed in water for a few minutes until the hæmoglobin is discharged, show the microfilariæ very well; it is advisable, however, for the novice at this sort of work to use, in the first instance, the fuchsin method described above.

Another plan is to fix the blood-film with alcohol, and then to stain by running on a few drops of saturated watery solution of methylene blue, washing off the superfluous stain after half a minute, and, if necessary, decolorizing with weak acetic acid and washing; the wet slide is then examined with the microscope. Or, without previous fixing with alcohol, the slide, after it has dried, may be dipped for a few seconds in distilled water so as to wash out the hæmoglobin, dried, and then, with or without fixing, stained with methylene blue, logwood, or other suitable stain.

An inch or half-inch objective and a mechanical stage with a parallel movement will enable the investigator to pass rapidly in review the whole of the blood on the slide. In unfixed slides, if microfilariæ are present, they will be detected readily; the hæmoglobin of the blood corpuscles being dissolved out by the watery stain, the nuclei of the white blood-corpuscles and any microfilariæ that may be present are the only coloured objects visible on the slide, and therefore at once catch the eye.

In any district in which the filaria is moderately common, out of 100 slides prepared in this way from as many individuals, probably eight or ten will be found to contain the parasite. When microfilariæ have been detected, the persons from whom the parasite-bearing slides came may be used afterwards as a source of supply for further examinations and study.

Demonstration of living microfilariæ.—When it is desired to study the living microfilaria, all that is necessary is to make three or four ordinary wet preparations of the blood of a filaria-infected person—making them during the evening or night, and ringing the cover-glasses with vaseline so as to prevent the slides from becoming dry. In such preparations, if kept cool, the microfilariæ remain alive for a week, or even longer, and can readily be detected by their movements, an inch or half-inch objective being used in the first instance as a searcher.

Permanent preparations.—Permanent preparations may be made by fixing very thin films of blood with alcohol or heat, staining with methylene blue, eosin, etc., and mounting in xylol balsam. It is generally advisable before fixing to wash out the hæmoglobin with water or very weak acetic acid. Logwood is perhaps the best stain; it brings out the sheath very distinctly, and picks out the nuclei. Double staining with eosin and logwood shows very well the structure of the musculo-cutaneous layer of the worm, in addition to other anatomical details.

Description of larval form.—Examined in fresh blood, *microfilaria bancrofti* (Fig. 97) is seen to be a minute, transparent, colourless, snake-like organism, which, without materially changing its position on the slide, wriggles about in a state of great activity, constantly agitating and displacing the corpuscles in its neighbourhood. At first the movements are so active that the anatomical features of the microfilaria cannot be made out. In the course of a few hours the movement slows down, and then one can see that the little worm is shaped like a snake or an eel; that is to say, that it is a long, slender, cylindrical organism, having one extremity abruptly rounded off, and the other for about one-fifth of the entire length gradually tapered to a fine point. On measurement, it is found to be a little over or under 0·3 mm. in length by 0·008–0·011 mm. in diameter—about the diameter of a red blood-corpuscle.

When examined with a low power, it appears to be structureless; with a high power a certain amount of structure can, on

close scrutiny, be made out. In the first place, it can be seen that the entire animal is enclosed in an exceedingly delicate, limp, structureless sack, in which it moves backwards and forwards (Fig. 97, *a*). This sack, or "sheath," as it is generally called, although closely applied to the body, is considerably longer than the worm it encloses; so that that part of the sack

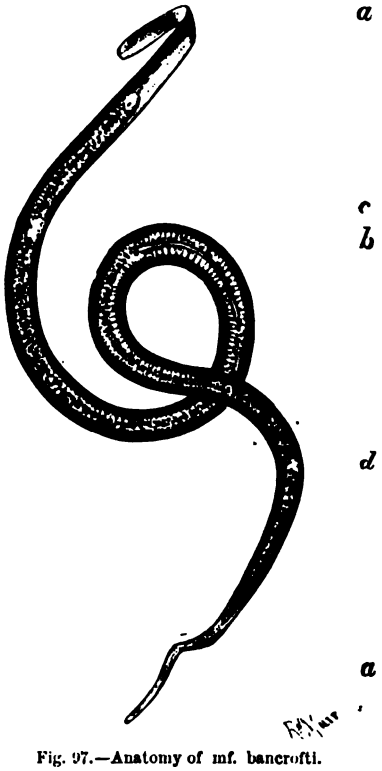


Fig. 97.—Anatomy of mf. bancrofti.
a a, Sheath; *b*, central viscus; *c*, V spot; *d*, tail spot.

which for the time being is not occupied is collapsed and trails after the head, or tail, or both, as the case may be. It can be seen also that, about the posterior part of the middle third of the parasite, there is what appears to be an irregular aggregation of granular material which, by suitable staining, can be shown to be a viscus of some sort (Fig. 97, *b*). This organ

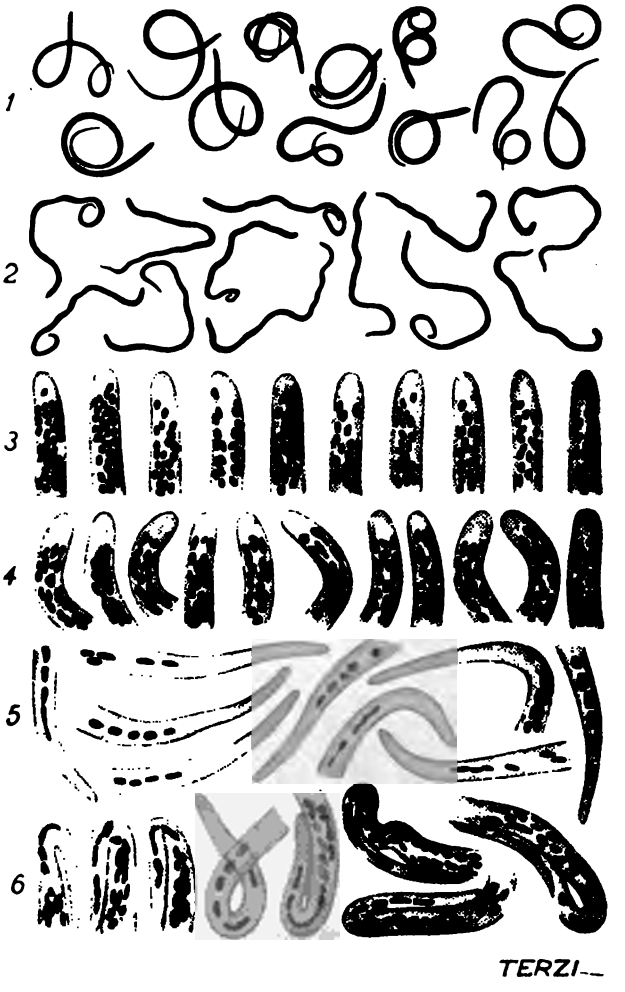
runs for some distance along the axis of the worm. Further, if a high power be used, a closely set, very delicate transverse striation can be detected in the musculo-cutaneous layer throughout the entire length of the animal. Besides this, if carefully looked for at a point about one-fifth of the entire length of the organism backwards from the head end, a shining, triangular V-shaped patch (Fig. 97, *c*) is always visible. What may be this V spot is brought out by very light staining with dilute logwood. The dye brings out yet another spot (Fig. 97, *d*), similar to the preceding, though very much smaller; this second spot is situated a short distance from the end of the tail. The former I have designated the "V spot," the latter the "tail spot." These spots are probably connected with development, the V spot being the rudiment of the future water-vascular system, the tail spot that of the anus or cloaca and posterior part of the alimentary canal. The spots (Fig. 97, *c*, *d*) are not stained by strong logwood or by the aniline dyes. Staining with logwood also shows that the body of the little animal is principally composed of a column of closely packed, exceedingly minute cells enclosed in a transversely striated musculo-cutaneous cylinder (Fig. 97); at all events, many nuclei are thereby rendered visible. Low has pointed out to me that the break seen in all stained specimens in the central column of nuclei occurs at a point slightly anterior to the V spot. This break can only be recognized in stained preparations.

Rodenwaldt and Fülleborn, by careful study of specially stained specimens, have further elucidated the histology of the microfilaria, which is fully illustrated in Figs. 98 and 128, borrowed from Fülleborn, special attention being directed to the excretory and genital cells and substances in the rudimentary intestinal canal.* (*See also* Plate XI.)

When the movements of the living microfilariæ have almost ceased, by careful focusing it can be seen that the head end is constantly being covered and uncovered by a six-lipped—or hooked—and very delicate prepuce; and, moreover, one can sometimes see a short fang of extreme tenuity, based apparently on a highly retractile granule, suddenly shot out from the uncovered extreme cephalic end, and as suddenly retracted (Fig. 99A, *c*, *d*).

Filarial periodicity.—A singular feature in the life of the microfilaria is what is known as "filarial periodicity."

* Rodenwaldt's method of vital staining with neutral red and azur II. is serviceable for demonstrating finer points of structure and morphological differences between different species. A large drop of blood is covered with a cover-slip and allowed to stand till the red blood-corpuscles have separated into rouleaux. A piece of thick blotting-paper is placed at the edge, and a dilute solution of the stain in 9 per cent. normal saline allowed to flow through. By these means the blood corpuscles are removed and the microfilariæ adhere to the cover-glass, becoming stained while still alive or freshly dead.



Distinguishing features between mf. bancrofti and mf. loa, in stained specimens.

Attitudes (1) of mf. bancrofti, (2) of mf. loa; heads (3) of mf. bancrofti, (4) of mf. loa; tails (5) of mf. bancrofti, (6) of mf. loa.

PLATE XI.

If under normal conditions of health and habit the blood be examined during the day, the parasite is rarely seen, or, if it be seen, only one or two specimens at most are encountered in a slide. It will be found, however, that as evening approaches, commencing about five or six o'clock, the microfilariæ begin to enter the peripheral circulation in gradually increasing numbers. The swarm goes on increasing until about midnight, at which time it is no unusual thing to find

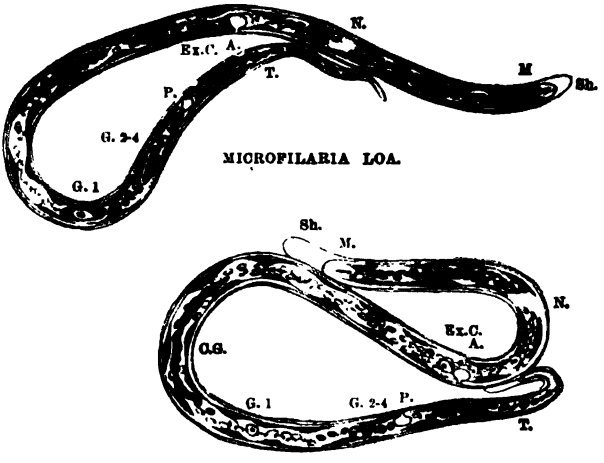


Fig. 98.—Minute anatomy of a microfilaria, and differential points of structure between mf. loa and mf. bancrofti. (*After Fülleborn.*)

N., Nerve ring (ant. break in cell column); A., ant. V-spot (exc. pore); Ex.C., excretory cell; C.G., granular mass (or Innenkörper); G. 1-4, "genital cells"; P., posterior or tail spot; M., granules in mouth cavity; T., granules in tail; Sh., sheath.

as many as three hundred, or even six hundred, in every drop of blood; so that, assuming that the parasites are evenly distributed throughout the circulation, it may be inferred that as many as forty or fifty millions are simultaneously circulating in the blood-vessels. After midnight the numbers begin gradually to decrease; by eight or nine o'clock in the morning the microfilariæ have disappeared from the peripheral

blood for the day. This nocturnal periodicity is, under normal conditions, maintained with the utmost regularity for years. Should, however, as Mackenzie has shown, a filarial subject be made to sleep during the day and remain awake at night, the periodicity is reversed; that is to say, the parasites come into the blood during the day and disappear from it during the night. It cannot be the sleeping state, as some have conjectured, that brings about this periodicity; for the ingress of the microfilariæ into the peripheral blood commences three or four hours before the usual time for sleep, and the egress several hours before sleep is concluded, and this egress is not complete until several hours after the usual time

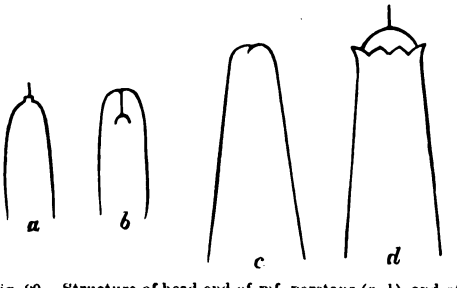


Fig. 90.—Structure of head end of mf. perstans (*a*, *b*), and of mf. bancrofti (*c*, *d*).

of waking. This night swarming of the larvæ of *F. bancrofti* in the peripheral circulation seems to be an adaptation correlated to the life-habits of its liberating agent, the mosquito, *Culex fatigans*, its usual intermediary host.

Some years ago I had an opportunity of ascertaining that during their diurnal temporary absence from the peripheral circulation the microfilariæ retire principally to the larger arteries and to the lungs, where, during the day, they may be found in enormous numbers.

The patient on whom this observation was made was the subject of lymph scrotum and varicose groin glands. His blood contained large numbers of embryo filariæ which

exhibited the anatomical features and periodicity characteristic of *microfilaria bancrofti*. One morning he committed suicide by swallowing a large quantity of dilute hydrocyanic acid. Death was almost instantaneous. At the post-mortem examination, made six hours later, a huge lymphatic varix was found occupying the pelvis and back part of the abdominal cavity. In the dilated lymphatic vessels many adult filariæ —*F. bancrofti*—were found. The distribution of the microfilariæ was studied by counting them in drops of blood expressed from the various organs, and also in sections. The result is summarized in the following tables:—

ENUMERATION OF MICROFILARIÆ IN A DROP OF BLOOD EXPRESSED FROM THE FOLLOWING ORGANS

Organ	No. of slides	Aggregate No. of microfilariæ	Average per slide
Liver	3	2	$\frac{2}{3}$
Spleen	3	3	1
Brachial venæ comites ...	4	111	28
Bone marrow	1	0	0
Muscle of heart	3	365	122
Carotid artery	1	612	612
Lung	10	6751	675

ENUMERATION OF MICROFILARIÆ IN SECTIONS OF THE FOLLOWING ORGANS

Organ	No. of sections	Aggregate No. of microfilariæ	Average per section
Liver	10	3	0·3
Spleen	4	0	0·0
Kidney	8	13	1·6
Brain	4	4	1·0
Muscle (voluntary)	3	2	0·33
Heart muscle	4	68	17·0
Lung	6	301	50·16
Lobe of ear	4	1	0·25
Scrotum	4	0	0·0

In the lung sections (Fig. 100) the microfilariæ lay outstretched or variously coiled in the vessels, large and small. In the heart muscle they lay along the capillaries between the fibres; in the kidneys they seemed specially to affect the Malpighian tufts; a very few were found in the capillaries of the brain; vast numbers were found in smears from the inner surface of the carotid arteries. The preparations afforded no explanation as to how the microfilariæ contrive to maintain their position in the blood current, or as to the forces

determining their peculiar distribution. Their absence from the liver and spleen is a remarkable fact.

Since this was written they have been found in the spleen tissue by other observers. The capillaries of the lung appear to be the favourite habitat of microfilariæ. *Microfilaria immitis*, *mf. perstans*, and the non-periodic Fijian microfilariæ have been found in greatest abundance in this situation.

Non-periodic microfilaria bancrofti.—Until recently it was believed that, in natural conditions of health and habit on the part of the human host, nocturnal periodicity was uniformly observed by

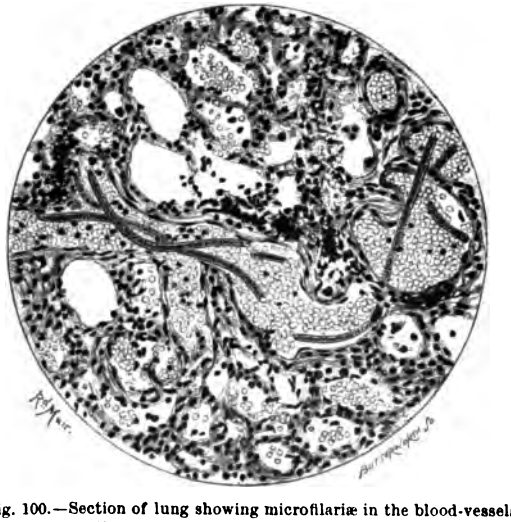


Fig. 100.—Section of lung showing microfilariæ in the blood-vessels. (*From a microphotograph by Mr. Spitta.*)

the microfilaria of *Filaria bancrofti* at all times and in any country. Many years ago Thorpe remarked that in Tonga and Fiji the filaria could be found often in great abundance in the blood during the daytime; and, in 1906, Ashburn and Craig found a microfilaria in the Philippines which showed no periodicity, and which these authors, relying on this feature, considered a distinct species and named

Stegomyia pseudoscutellaris, ♀.

PLATE XII.

F. philippinensis. Wilson, in 1909, after a systematic study of the point in a considerable number of cases in Fiji, also considered that the local filaria was non-periodic—an observation amply confirmed by Bahr in 1910. Similarly, Fülleborn found that the microfilaria of Samoa showed no periodicity. Strange to say, the filaria of neighbouring islands in the Pacific—namely, the Solomons, New Guinea, and the Bismarck Archipelago—are strictly periodic in their blood appearances.

Bahr has shown that the filaria of Indian immigrants who had acquired their filarial infections in India retain their periodic habits during at least three years of residence in Fiji, and that if an Indian or a Solomon Islander acquires the infection in Fiji the microfilariæ are non-periodic in habit. Connal and Thiroux, in a proportion of instances of filarial infection in West Africa, have found the microfilariæ to be non-periodic,* whilst in other instances they exhibit the nocturnal habit just as those of India, China, and America are known to do.

As an explanation of this striking anomaly it has been suggested that the non-periodic microfilaria is the progeny of a parent worm specifically distinct from *F. bancrofti;* but Leiper has failed to find any difference between the Fijian mature worm and the *F. bancrofti* of India, China, and South America; and Fülleborn and Bahr, after minute study and comparison of the histology of the microfilaria from those countries, find that they are identical in every respect. It may be, as Bahr suggests, that the non-periodic habit of the Pacific microfilaria is a partial adaptation to the day habit of its usual intermediary in Fiji *Stegomyia pseudoscutellaris.* (Plate XII.)

The subject of filarial periodicity, especially as regards the blood worms of the Pacific islands and West Africa, requires further study.

The mosquito the intermediary host of *Filaria bancrofti* [illegible]

* I [illegible] night [illegible] case the [illegible]

species of mosquito * which have fed on the blood of a filaria-infested individual be examined immediately after feeding, the blood contained in the stomach of the insects will be found to harbour large numbers of living microfilariæ. If one of these mosquitoes be examined three or four hours after it has similarly fed, it will be found that the blood corpuscles have in great measure parted with their hæmoglobin, and that the blood plasma in consequence of this and of dehydration has become thickened, although not coagulated. If attention be directed to the microfilariæ in the thickened blood, it will be seen that many of them are actively engaged in endeavouring to escape from their sheaths. The diffused hæmoglobin has so thickened the blood plasma that it has become viscid, and holds, as it were, the sheath. This change in the viscosity of the blood seems to prompt the microfilariæ to endeavour to escape from their sheaths. They become restless, as if excited. Alternately retiring towards the tail end and then rushing forward to the head end of the sheath, the imprisoned parasite butts violently against the latter in frantic

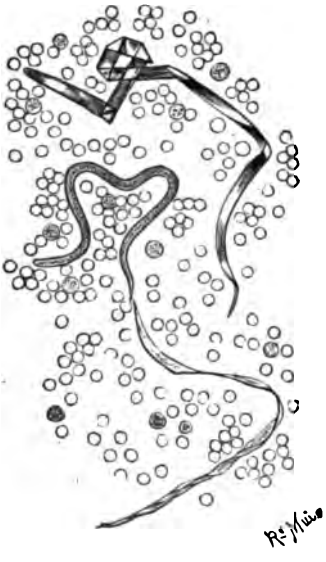


Fig. 101.—Filarial ecdysis.

* Several species of mosquitoes may subserve *F. bancrofti*, viz.: *Culex fatigans*, *Mansonia uniformis* and *titillans*, *Anopheles maculipennis*, *Myzomyia rossii*, *Myzorhynchus nigerrimus*, *minutus*, and *funestus*, *Pyretophorus costalis*, *Cellia argyrotarsis*, *Stegomyia pseudoscutellaris* (*Stegomyia fasciata* probably occasionally). *Culex fatigans* is the first in which it was found.

efforts to escape. After a time, the majority succeed in effecting a breach and in wriggling themselves free from the sheaths which had hitherto enclosed them (Fig. 101).* The microfilaria now swims free in the blood, the character of its movements once more undergoing a remarkable change. Hitherto, though active enough in wriggling about, the parasite did not materially change its position on the slide; but

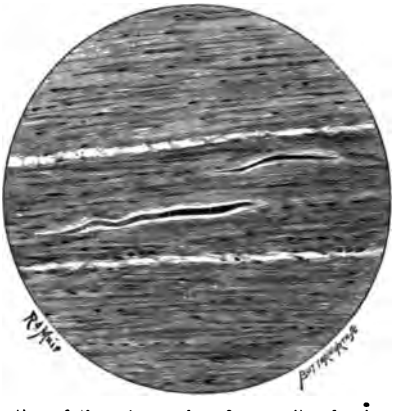


Fig. 102.—Section of thoracic muscles of mosquito, showing microfilariæ between the fibres: first day after the insect has fed on a filariated patient. (*From a microphotograph by Mr. Spitta.*)

now, having become free, it moves about from place to place—locomotes, in fact. If we dissect a mos-

* This casting of its sheath by the microfilaria can be induced in ordinary blood slides by chilling them on ice, or by otherwise bringing about the diffusion of the hæmoglobin. The following method is usually successful: Ring with vaseline the cover-glasses of several ordinary wet preparations of finger blood obtained at night from a filarial patient; wrap the preparations separately in filter paper and lay them, enclosed in a watertight tin box, on a block of ice for six or eight hours—say overnight. Next morning examine them with the microscope. It will be found, as the chilled slides warm up, that wherever on the slides the hæmoglobin has become diffused and the blood laky, the microfilariæ, as they gradually revive from the chilling, begin to endeavour to break through their sheaths. By evening most of them have effected this, and their empty sheaths can be seen lying scattered about in the viscid blood. The blood must not be frozen.

quito at a somewhat later period after feeding, it will be found that the stomach of the insect, though still full of blood, contains very few microfilariæ, although their empty sheaths can be seen in abundance. If, however, we break up with needles the thorax of the insect and tease out in normal salt solution the muscular tissue, we shall find that the microfilariæ, after discarding their sheaths, have

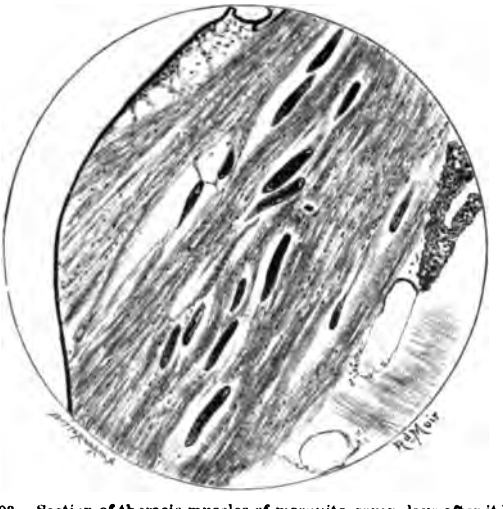


Fig. 103.—Section of thoracic muscles of mosquito seven days after it had fed on a filariated patient. (*From a microphotograph by Mr. Spitta.*)

quitted the stomach and entered the thoracic muscles of the insect, among the fibres of which they are now moving languidly. (Figs. 102–8.) By a course of serial dissections of filariated mosquitoes we can ascertain that in the thorax of the insect the parasite enters on a metamorphosis which takes from twelve to twenty days (longer or shorter, according to atmospheric temperature) to complete — a metamorphosis eventuating in the formation of a mouth, of an alimentary canal, and of a peculiar trilobed caudal end, as well as in a relatively

enormous increase in the size (to $\frac{1}{16}$ in.) and activity of the young parasite. The filariæ now quit the thorax.

A few find their way to the abdomen, where, in properly prepared sections, they may occasionally be seen in the tissues around the stomach, and even among the eggs at the posterior part of the abdomen. The vast majority pass forwards by the prothorax

Fig. 104.—Section of thoracic muscles of mosquito about twelve days after it had fed on a filariated patient. (*From a microphotograph by Mr. Spitta.*)

and neck, and, entering the head, coil themselves up close to the base of the proboscis and beneath the pharynx and under-surface of the cephalic ganglia. Low, in sections prepared at the London School of Tropical Medicine from filariated mosquitoes sent to me by Bancroft, of Australia, has shown that the filaria in its future progress finds its way into the proboscis; an observation which has been confirmed by James in India, Annett and Dutton in West Africa, Bahr in Fiji, and others elsewhere.

As pointed out by Grassi, its exact position here is the interior of the labium (Fig. 107, *a*). Apparently the filariæ seek to emerge (for such must be their object in entering the proboscis) in pairs; at all events, in those sections which I have examined, two worms were in each instance found together, their heads abreast of each other and close to the termination of the labium in the labella. As many

Fig. 105.—Larval filariæ (Dirofilaria immitis), leaving proboscis of mosquito and burrowing through the skin. (*Partly diagrammatic, after Fülleborn.*)

as eight have been found packed together in this situation.

The parasites remain in this position awaiting an opportunity to enter a warm-blooded vertebrate host when the mosquito next feeds on such. This they appear to do by penetrating the thin membrane that unites the labella to the tip of the proboscis, and so passing on to the surface of the skin, which they penetrate in the neighbourhood of the puncture made

by the mosquito * (Fülleborn, *Dirofilaria immitis;* Bahr, *Filaria bancrofti*) (Fig. 105); they do not enter through the mosquito-made wound, as formerly conjectured, but near it. Apparently the filariæ in some instances can discriminate between flesh and vegetable, for in mosquitoes fed on bananas the parasites

Fig. 106.—Section of mosquito about sixteen days after it had fed on a filariated patient. The filaria has escaped from the thoracic muscles. (*From a microphotograph by Mr. Spitta.*)

had not been deceived into passing into so inhospitable a medium: up to forty days after the insect was

* Annett and Dutton pointed out that there is a weak point in the chitinous skeleton of the labium just where the labella are jointed on, and suggested that it is at this weak point that the parasites escape. Bancroft confirmed this suggestion by showing that the filariæ enclosed within the labium will escape readily at this point under the least pressure. Noè also, in a more recent paper, agrees with Annett and Dutton and rejects his former hypothesis (held in common with Grassi) to the effect that the filariæ escape through a rupture in the contiguity of the labium when it is buckled up during haustellation. Noè satisfied himself by numerous experiments that the filariæ invariably die when extruded at the seat of the bend. Finally, Lebredo, by actual experiment, proved that the filariæ escape in this way. He placed living mosquitoes on slides, irrigated them with a weak saline

infected, and after many meals of banana they could still be found coiled up in the head or stretched out in the labium. Probably heat and moisture play a part in this respect, as has been shown to be the case by Fülleborn.

Fig. 107.—F. bancrofti in head and proboscis of mosquito.
a, a, a, Filariæ; *b*, labium; *c*, labrum; *d*, base of hypopharynx; *e*, duct of veneno-salivary gland; *f, f*, cephalic ganglia; *g, g*, eye; *h*, œsophagus; *i*, pharyngeal muscle.

These observations prove that, like the malaria parasite, the filaria is introduced into its human

solution, and placed them on the stage of the microscope. He separated the various parts of the proboscis by a slight pressure so as to observe more clearly, and placed the flame of a Bunsen burner close to the slide. He noticed that the filariæ moved violently within the labium when the liquid in which the mosquito was bathed attained a higher temperature. Finally, one managed to pierce its way through at the tip of the labium, and was soon followed by others. He noticed the escape of five filariæ within a minute. Sometimes two passed simultaneously. Too high a temperature killed both larvæ and mosquito. A fall of temperature arrested the process.

definitive host by mosquito bite. Whether it may obtain an entrance by any other channel or medium it would be hard to prove and rash to deny. That the young filaria can live in water for a time (about seven hours) is certain; it is conceivable that some of them, such as those which at the completion of their stage of development in the mosquito find their way into the abdomen of the insect, may escape into water when the mosquito lays her eggs or dies.*

Technique.—Mr. Max Colquhoun made for me beautiful sections illustrating the metamorphosis of the filaria in mosquito by the following technique. The insects, preserved in glycerine, were soaked in dilute acetic acid 5 per cent. for one day only; then in formalin 50 per cent., water 50 per cent., for one day; next in absolute alcohol for one day; *absolute* alcohol and ether, equal parts, one day; finally in celloidin for one day. They were then sectioned, placed in strong hæmatoxylin for two hours, decolorized in acid hydrochloric 1 per cent. and alcohol, washed in water, passed through aniline oil, xylol, and mounted in xylol balsam. Paraffin sections are not a success.

In working with fresh mosquitoes, all that is necessary is to tease up the thorax of the insect with needles in normal salt solution, and, after removing the coarse fragments of the integuments of the mosquito, apply a cover-glass and place under an inch objective. The filariæ are readily detected. If the slide is dried, fixed, and stained with a watery solution of some aniline dye or with logwood, and mounted in xylol balsam, beautiful permanent preparations will be obtained.

* In my original observations on this subject in 1879 and 1883 (*Trans. Linnean Soc.*, 1883) I supposed that filarial metamorphosis, so far as the mosquito was concerned, is completed in from six to seven days. This I now believe was too short an estimate. Bancroft (*Journ. of Trop. Med.*, 1899) has since shown that it is necessary to feed the experimental mosquito (at all events, *C. fatigans*), so as to keep it alive for at least sixteen days, to obtain the final stages of the metamorphosis. (Fig. 106.) I have little doubt now that the insects on which my observations were made had fed repeatedly, without my being aware of it, after their meal on the filariated patient. Bancroft has shown that by proper feeding (he used banana for the purpose) mosquitoes may be kept alive for several months, any filariæ they happen to harbour remaining alive, but not advancing in development beyond the final stage alluded to in the above description. In the observations referred to I conjectured that the fully metamorphosed filaria escaped from the insect either at her death or when she deposited her eggs, and that thus, in drinking-water, it obtained a chance of gaining access to the stomach of a human host. Before Low's observation Bancroft had very nearly guessed the truth, for he had expressed the idea that the filaria may be injected into man by the mosquito when it re-feeds, or that it may be swallowed by man while it is still enclosed in its intermediary insect host.

Once introduced into the human body, the filaria finds its way into the lymphatics. Arrived in one of these, it attains sexual maturity, fecundation is effected, and in due course new generations of larval filariæ are poured into the lymph. These, passing through the glands—if such should intervene—by way of the thoracic duct and left subclavian vein or by the lymphatics of the upper part of the body, finally appear in the circulation.

Such is the life history of *Filaria bancrofti;* man is its definitive host, the mosquito its intermediary host. It is manifest that filarial periodicity is an

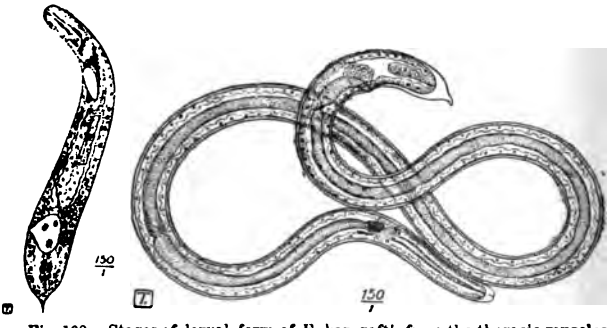


Fig. 108.—Stages of larval form of F. bancrofti, from the thoracic muscles of Culex fatigans. (*After Looss.*)

adaptation of the habits of the parasite to the nocturnal habits of the mosquito. It is also manifest that the purpose of the "sheath" with which it is provided while circulating in the human host is to muzzle the young filaria and prevent its breaking through the blood-vessels, and thereby missing its chance of gaining access to the mosquito. The cephalic armature is adapted for piercing the walls of the mosquito's stomach, and for enabling the parasite to travel through the tissues of the insect.

Anyone desirous of working out for himself the metamorphosis of the filaria in the mosquito can readily do so, even in the absence of a suitable human subject, by setting Anopheles mosquitoes to bite filariated dogs. In most tropical countries a large proportion of the dogs harbour *Filaria* (*Dirofilaria*)

immitis, whose larvæ circulate in the blood and are taken up by mosquitoes in the same way as *F. bancrofti*. (Fig. 109.) Grassi and Noè (confirmed by Bancroft, Sambon, and Low) have shown that the embryo *F. immitis* passes through the earlier stages of its metamorphosis in the Malpighian tubes of

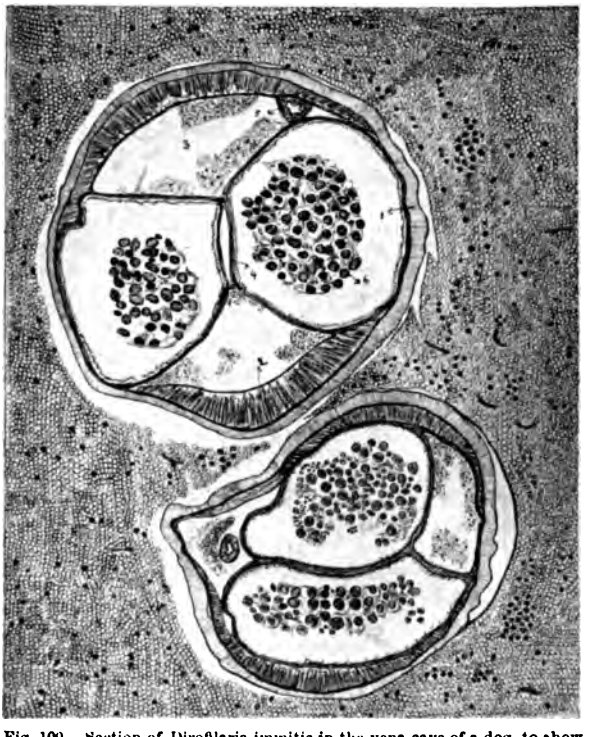


Fig. 109.—Section of Dirofilaria immitis in the vena cava of a dog, to show the structure of a filaria on transverse section. Embryos are seen amongst the surrounding blood-cells. (*After Bahr.*)

1, Cuticle; 2, muscle cells; 3, perivisceral cavity; 4, inter-uterine septum; 5, alimentary canal; 6, ova.

Anopheles, whence, on attaining a certain stage of development, it passes forwards to the head of the insect, where it behaves in much the same way as *F. bancrofti*.

Parental forms.—The parent filariæ have been found many times. They are long, hair-like, transparent

nematodes, 3-4 in. in length (Fig. 110). The sexes live together, often inextricably coiled about each other. Sometimes they are enclosed, coiled up several in a bunch and tightly packed, in little cyst-like dilatations of the distal lymphatics (Maitland); sometimes they lie more loosely in lymphatic varices; sometimes they inhabit the larger lymphatic trunks between the glands, the glands themselves, and, probably not infrequently, the thoracic duct.

The *female filaria* is the larger, both as regards length and

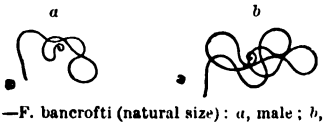


Fig. 110.—F. bancrofti (natural size): *a*, male; *b*, female.

thickness. It measures 85–90 mm. in length by 0·24–0·28 mm. in breadth. The two uterine tubes, occupying the greater extent of her body, are filled with ova at various stages of development. In both sexes the oral end, armed with a double row (number uncertain) of exceedingly minute papillæ (Fig. 111, *b*), is slightly tapered, club-shaped and simple; the tail (Fig. 111, *a*, *c*) also is tapered to comparatively small dimensions, its tip being rounded off abruptly. The vagina opens

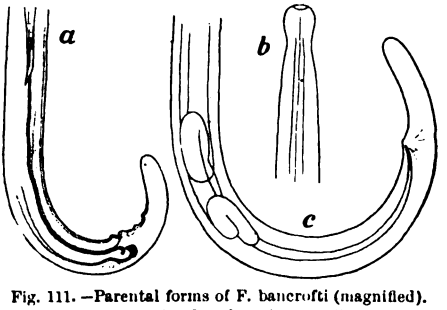


Fig. 111.—Parental forms of F. bancrofti (magnified).
a, Tail of male; *b*, head and neck; *c*, tail of female.

on the ventral surface about 1·2–1·3 mm. from the anterior extremity; the anus just in advance of the tip of the tail. The cuticle is smooth and without markings.

To the naked eye the *male worm* is characterized by its slender dimensions (about 40 mm. in length by 0·1 mm. in diameter), by its marked disposition to curl, and by the peculiar vine-tendril-like tail, the extreme end of which is sharply incurvated (Fig. 110, *a*). The cloaca gives exit to two slender, unequal spicules (0·2 and 0·6 mm. respectively). The exist-

ence of caudal papillæ in the male worm has been ascertained by Leiper. There are in all two rows of fifteen each, extremely minute, mainly arranged around the anus.

The life-span of *F. bancrofti* and its microfilaria have not been determined. From the fact that the microfilariæ have been found in the blood many years after the opportunity of infection has passed, it is to be concluded that both of them may live for many years. Experiments with the microfilaria of *Filaria* (*Dirofilaria*) *immitis* have shown that in the case of

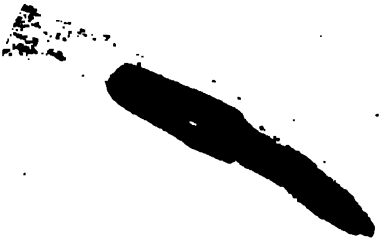


Fig. 112.—Calcified F. bancrofti lying in and blocking a lymphatic vessel. (*After Bahr*)

this worm the microfilaria may live for at least three years, and in this time acquire somewhat increased dimensions, but it does not follow that the inference from these experiments is applicable to *microfilaria bancrofti*. I have seen the latter completely disappear from the circulation within a few hours of the death of the parent worm during an attack of lymphangitis. Nothing is known of what becomes of the microfilariæ when they are effete or die.

As shown by Wise and Bahr, the mature worm becomes cretified after its death, and may be found, sometimes in large numbers, in this condition in the lymphatic vessels and glands. (Figs. 112, 113.)

Morbid anatomy and pathology. *The filaria not generally pathogenic.*—In most cases of filarial infection the parasite exercises no manifest injurious influence whatever. In a certain proportion of instances, however, there can be no doubt that it does have a very prejudicial effect on its host; and this mainly by obstructing lymphatics. The

Fig. 113.—Section of a fibrosed lymphatic gland. (*After Bahr.*)
A, Portions of a calcified F. bancrofti; B, partially occluded lymphatic vessel.

healthy, fully-formed microfilariæ—that is to say, the larval filariæ which, by means of the microscope, we see in the blood—have, so far as we can tell, no pathogenic properties whatever; the parent worm and the immature products of conception, alone, are dangerous.

Filarial disease originating in injury of lymphatic systems.—Roughly speaking, the filaria causes two types of disease: one characterized by varicosity of

lymphatics, the other by more or less solid œdema. The exact way in which the parasite operates has not been definitely and absolutely ascertained for all types of filarial disease. Apparently, in some instances, a single worm, or a bunch of worms, may plug the thoracic duct, and act as an embolus or originate a thrombus; or the worm may give rise to inflammatory thickening of the walls of this vessel, and so lead to obstruction from the consequent stenosis or thrombosis. In other instances the minor lymphatic trunks and the glands may be similarly occluded. As an effect of either form of occlusion, the lymphatic areas drained by the implicated vessels are cut off from the general circulation, and varicosity or œdema, or both, ensue.

Pathology of lymphatic varix.—In consequence of the rich anastomosis existing between the contiguous lymphatic areas, on filarial obstruction occurring in one of them a compensatory lymphatic circulation is sooner or later established. But before this can be properly effected a rise of lymph pressure and a dilatation of the lymphatics in the implicated area must take place. This leads to lymphatic varix of different kinds, degrees, and situations. When the seat of filarial obstruction is the thoracic duct, the chyle poured into that vessel can reach the circulation only by a retrograde movement; consequently, this fluid may be forced to traverse in a retrograde way the abdominal and pelvic lymphatics, the lymphatics of the groin, scrotum, and abdominal wall. As a consequence, these vessels, together with the thoracic duct up to the seat of obstruction, become enormously dilated. In dissections of such cases (Fig. 114) the thoracic duct has been found distended to the size of a finger, the abdominal and pelvic lymphatics forming an enormous varix, perhaps a foot in diameter and many inches in thickness, concealing kidneys, bladder, and spermatic cords. In such cases, when one of the vessels of the varix is pricked or ruptures, the contents are found to be white or pinkish. They are not limpid like ordinary lymph. They are chyle,

therefore; chyle on its way to enter the circulation by a retrograde compensatory track. When the varix involves the integuments of the scrotum, the result is "lymph scrotum"; when most prominent in the groin, then a condition of glands is produced which I have called "varicose groin glands"; when the lymphatics of the bladder or kidneys are affected and rupture from over-distension, then chyluria is the result; when those of the tunica vaginalis rupture,

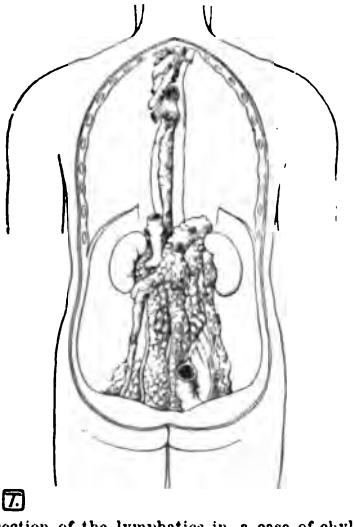


Fig. 114.—Dissection of the lymphatics in a case of chyluria, showing the dilated right and left renal lymphatics and thoracic duct. (*Mackenzie, Trans. Path. Soc., Lond.*)

then there is chylous dropsy of that sac—"chylocele"; the same may happen in the peritoneum—chylous ascites. Occasionally varicose lymphatic glands, resembling those frequently encountered in the groins, are found in the axilla. Occasionally, also, limited portions of the lymphatic trunks of the limbs are similarly and temporarily, or more permanently distended. This, doubtless, is the pathology of all those forms of filarial disease characterized by visible varicosity of

lymphatics, with or without lymphorrhagia. It may happen that the obstruction is in some lymphatic tract on the distal side of the entrance of the chyle-bearing vessels into the receptaculum chyli. In this case a rupture of the consequent lymphatic varix will give issue to lymph unmixed with chyle.

Filariæ may disappear from the blood in such cases.—In filarial disease associated with lymphatic varix, microfilariæ are generally present in the blood as well as in the contents of the dilated vessels. Sometimes, it is true, the microfilariæ are not found. Such cases are probably of long standing; had the microfilaria been looked for at an earlier stage of the disease, it would probably have been discovered. I have watched cases in which the larva has disappeared in this way; though at first found in abundance in the blood, after a year or longer it ceased to appear there. The reason for this disappearance is doubtless the death of the parent parasites, an occurrence I have seen associated with attacks of acute lymphangitis. Although the original cause of the varix may thus disappear, the effect is permanent.

Pathology of elephantiasis arabum. *Microfilariæ not usually present in the blood in elephantiasis.*—In those cases of filarial disease in which elephantiasis arabum is the leading feature, it is not usual at any stage of the established disease to find microfilariæ in the blood or elsewhere, unless it be in countries in which filariasis is extremely common and reinfection, or extensive infection, highly probable.

Reasons for regarding elephantiasis as a filarial disease.—From this circumstance—the absence of microfilariæ from the blood in elephantiasis—the question naturally arises, Why attribute this disease to the filaria? The answer to this is: (1) The geographical distribution of *Filaria bancrofti* and of elephantiasis arabum corresponds; where elephantiasis abounds there the filaria abounds, and vice versa. (2) Filarial lymphatic varix and elephantiasis occur in the same districts, and frequently concur in the same individual. (3) Lymph scrotum, an unquestionably filarial disease, often terminates in elephantiasis of

the scrotum. (4) Elephantiasis of the leg sometimes supervenes on the surgical removal of a lymph scrotum. (5) Elephantiasis and lymphatic varix are essentially diseases of the lymphatics. (6) Filarial lymphatic varix and true elephantiasis are both accompanied by the same type of recurring lymphangitis. (7) As filarial lymphatic varix is practically proved to be caused by the filaria, the inference that the elephantiasis of warm climates, with rare exceptions —the disease with which the former is so often associated and has so many affinities—is attributable to the same cause, appears to be warranted.

Explanation of the absence of microfilariæ in the blood in elephantiasis.—If the filaria be the cause of tropical elephantiasis, how account for the absence of filaria larvæ in the blood, as is the case in the vast majority of instances of this disease? The answer is: Either the disease-producing filariæ have died; or the lymphatics draining the affected area are so effectually obstructed by the filaria, its products, or its effects, that any microfilariæ they may contain, or may have contained, cannot pass along these vessels to enter the circulation. Adult filariæ of both sexes in large numbers may be found in enlarged fibrosed lymphatic glands—epitrochlear, for example—without the presence of the corresponding microfilariæ in the blood stream.

We have already said that in filarial lymphatic varix the parasites which produced the disease may die, particularly during attacks of lymphangitis; we have also seen that they may become cretified and may be found in large numbers in this condition or alive in the glands and lymphatic trunks, where, as Bahr has shown, they give rise to giant-cell formation and fibrotic changes of an obstructive nature. (Figs. 112, 113.) I do not think, however, that this is the entire explanation of the origin of elephantiasis.

Lymph stasis produced by filaria ova.—I have twice in filariasis found ova of the filaria in lymph; once in the lymph from a lymph scrotum, once in lymph procured by aspirating a varicose groin gland. Therefore, at times, the filaria may produce ova

instead of swimming larvæ. The ova of the filaria are not like the long, supple, slim, active, swimming larvæ; they are passive, more or less rigid oval bodies nearly five times the diameter of the embryo coiled up in their interior. In consequence of their size and passive character the ova, unlike the normal free-swimming larvæ, are quite incapable of traversing such lymphatic glands as, in the event of their escape from the parental worm, they may be carried to passively by the lymph stream. It is an accepted fact in pathology that an essential element in the causation of elephantiasis is lymph stasis. I have ventured to conjecture that the stasis of lymph which eventuates in *tropical* elephantiasis is in some instances produced by embolism of the lymphatic glands by ova of the filaria.

If ova are expelled by the parent filaria, it must be as a result of some hurrying of the process of filarial parturition. That this does occur sometimes the discovery, already mentioned, of filaria ova in the lymph fully proves. We can readily understand how, in consequence of mechanical injury, to which from her exposed position in the limbs she must be frequently subjected, or of some other cause, the parent filaria may miscarry. Should this happen, then the contents of her uterus will be expelled prematurely, and before the ova, normally lying at the upper part of her uterus, have become the long, outstretched, active larvæ we see in the blood. If a crowd of these passive, massive ova are carried by the lymph stream to the lymphatic glands of a limb, in the lymphatic trunks of which a female filaria is lying aborting, embolism of the afferent lymphatics of the glands must result and stasis of lymph in the limb ensue.

Inflammation necessary for the production of elephantiasis.—Lymph stasis alone does not produce elephantiasis; this has been proved by experimental ligature of lymphatic trunks. It may produce a form of œdema, but not true elephantoid hypertrophy. Should inflammation occur in an area of lymphatic congestion so produced, as it is very apt to do on the

slightest injury, then elephantiasis will supervene; for, unless the lymphatics of an inflamed area are patent, the products of inflammation are not completely absorbed. Erysipelatoid inflammation, frequently recurring, is a well-recognized feature of almost every case of elephantiasis arabum.

Sequence of events in elephantiasis.—The sequence of events in the production of elephantiasis is, I believe, as follows: Parent female filaria in the lymphatic system of the affected part; obstructive fibrotic changes in the glands or lymphatic trunks; or injury of the filaria leading to premature expulsion of ova; and embolism of lymphatic glands supervening on either of these causes of obstruction; stasis of lymph; lymphangitis from subsequent traumatism or other cause (as septic infection) in the congested area; imperfect absorption of the products of inflammation; recurring attacks of inflammation leading to gradual, intermittently progressive, inflammatory hypertrophy of the part.

In this way I explain the production of elephantiasis by the filaria. And in this way I explain the absence from the blood of the larvæ of the parasite which started the disease; they cannot pass the occluded glands. Very likely the parent worm or worms die at an early stage of the disease, killed by the subsequent lymphangitis, or by the cause which led to premature parturition.

The subjects of elephantiasis less liable than others to microfilariæ in the blood.—Some years ago I made a curious observation which supports the view just stated. I received from Surgeon-Major Elcum 88 slides of night blood from 88 natives of Cochin. Of these 88 persons, 14 were affected with elephantiasis, 74 were not so affected. Of the slides coming from the 74 non-elephantiasis cases, 20 contained microfilariæ, one in every 3½; of the 14 elephantiasis cases, only 1 had microfilariæ. Why should the elephantiasis cases have proportionately fewer microfilariæ than the non-elephantiasis cases? The answer may be, that in the former the existence of elephantiasis implied that a large area of their lymphatic systems

was blocked, and the blood could be stocked with microfilariæ carried by the lymph from only a relatively small lymphatic area; and that there was, therefore, a proportionately lesser likelihood of the presence of parent filariæ having for their young an unobstructed passage to the blood.

Filarial Diseases

Enumeration of the filarial diseases.—The diseases known to be produced by *Filaria bancrofti* are abscess; lymphangitis; arthritis; synovitis; abscess of hip-joint; varicose groin glands; varicose axillary glands; lymph scrotum; cutaneous and deep lymphatic varix; orchitis; funiculitis; chyluria; elephantiasis of the leg, scrotum, vulva, arm, mamma, and elsewhere; chylous dropsy of the tunica vaginalis; chylous ascites; chylous diarrhœa, and probably other forms of disease depending on obstruction or varicosity of the lymphatics, or on death of the parent filariæ, including peritonitis and secondary infection by pyogenic micro-organisms (Wise and Minett).

Abscess.—Occasionally, as already mentioned, whether in consequence of blows or other injuries, of lymphangitis, or of unknown causes, the parent filariæ die. Generally the dead body is absorbed, just as a piece of aseptic catgut would be, or becomes cretified.* Sometimes the dead worm acts as an irritant and causes abscess, in the contents of which fragments of the filaria may be found. Such abscesses, occurring in the limbs or scrotum, will discharge in due course, or may be opened; they lead to no further trouble. Should they form in the thorax or abdomen, serious consequences and even death may ensue.

Probably, in certain instances, abscess forms at times independently of the death of the parasite; e.g. in varicose glands, in lymph scrotum, in elephantiasis.

* Wise and Minett, during the last few years, have found filariæ living, or cretified, in the following situations, viz. pelvis of kidney (31 times), epididymis (18 times), retroperitoneum (12 times), the ilio-psoas muscle (4 times), Glisson's capsule (twice), inguinal glands (25 times), lymphatic vessels (8 times). Similar observations have been made by Bahr in Fiji.

The death of the parent filaria is apt to be lost sight of as a possible cause of abscess in the subjects of filarial infection. Deep-seated pain in the thorax or abdomen, with inflammatory fever followed by hectic, and a diminution in the number of microfilariæ in, or their entire disappearance from, the peripheral blood, should in such circumstances suggest a diagnosis of filarial abscess and indicate exploration and, if feasible, active surgical interference.

Lymphangitis and elephantoid fever. *Symptoms.*—Lymphangitis is a common occurrence in all forms of filarial disease, particularly in elephantiasis, varicose glands, and lymph scrotum. When occurring in the limbs the characteristic painful, cord-like swelling of the lymphatic trunks and associated glands, and the red congested streak in the superjacent skin, are usually apparent at the commencement of the attack. Very soon, however, the connective tissue and skin of the implicated area become inflamed and tense, and high fever, preceded by severe and prolonged rigor, sets in. The attack may continue for several days, and be accompanied by severe headache, anorexia, often vomiting, and sometimes delirium. After a time the tension of the inflamed integuments may relieve itself by a lymphous discharge from the surface. Usually the attack ends in profuse general diaphoresis. The swelling then subsides gradually though not entirely. Lymphangitis may be confined to groin glands, testis, spermatic cord, or abdominal lymphatics. When it affects an extensive abdominal varix, symptoms of peritonitis are rapidly developed and may prove fatal.

Diagnosis.—This fever, appropriately named by Fayrer "elephantoid fever," occurs habitually at varying intervals of weeks, months, or years, in nearly all forms of elephantoid disease. Its tendency to recur, the severe rigor ushering it in, and the terminal diaphoresis cause it to be mistaken for ague. In Barbados, where there is no malaria, it is habitually called "ague." The implication of the lymphatics, the local pain, the erysipelatoid redness and swelling, the prolonged pyrexial stage, the

absence of the malaria parasite from the blood, the presence there very possibly of microfilariæ, and the powerlessness of quinine to control the fever, suffice for diagnosis. Nevertheless, error in diagnosis is common, particularly when the attacks recur frequently and with a certain degree of regularity, as is usually the case.

Treatment.—The treatment should consist in removing any cause of irritation, in rest, elevation of the affected part, cooling lotions or warm fomentations, mild aperients, opium or morphia to relieve pain, and, if tension is great, pricking or scarifying the swollen area under suitable aseptic conditions. Subsequently the parts, if their position permits, should be elevated and firmly bandaged.

Varicose groin glands (Figs. 115, 116).—Varicose groin glands are frequently associated with lymph scrotum, with chylous dropsy of the tunica vaginalis, or with chyluria. Occasionally all four conditions coexist in the same individual.

Symptoms.—As a rule the patient is not aware of the existence of these varicose glands until they have attained considerable dimensions. Then, a sense of tension, or an attack of lymphangitis, calls attention to the state of the groins, where certain soft swellings are discovered. These swellings may be of insignificant dimensions or they may attain the size of a fist. They may involve both groins, or only one groin; they may affect the inguinal glands alone, or the femoral glands alone, or, and generally, both sets together.

To the touch they feel soft, doughy, and obscurely lobulated. The skin, natural in appearance, can be glided over the surface, but the swellings themselves are not movable over the subjacent fascia. Occasionally hard, kernel-like pieces can be felt in their interior, or the entire mass may be more or less indurated. On thrusting a hypodermic needle into the swellings, white or reddish chylous, or clear lymphous fluid can be aspirated, sometimes in great abundance. This fluid coagulates rapidly, and usually contains living microfilariæ or filarial ova.

Diagnosis.—It is important to be able to diagnose these tumours from hernia, for which they are often mistaken. This can be done by observing that they are not tympanitic on percussion; that though pressure causes them to diminish, they do so slowly; that there is no sudden dispersion accompanied by gurgling, as in hernia, on taxis being employed; that they con-

Fig. 115.—Varicose groin glands and chylocele. (*From a patient under the care of Mr. Johnson Smith.*)

vey a relatively slight or no impulse on coughing; that they slowly subside on the patient lying down, and slowly return, even if pressure be applied over the saphenous or inguinal openings, on the erect posture being resumed. The cautious use of the hypodermic needle will confirm diagnosis; which would be further strengthened by the coexistence of lymph scrotum, chyluria, or chylous hydrocele, and the presence of filariæ in the blood. *Chronic swellings about the groin,*

cords, testes, and scrotum in patients from the tropics should always be regarded as being possibly filarial.

Pathological anatomy.—On dissection these tumours are found to consist of bunches of varicose lymphatics, and, it may be, to form part of a vast lymphatic varix involving the pelvic and abdominal lymphatics.

Treatment.—Unless they give rise to an incapacitating amount of discomfort, and are the seat of fre-

Fig. 116.—Unusually large varicose groin glands. (*From photograph: Journ. of Trop. Med.*)

quent attacks of lymphangitis, varicose groin glands are best left alone. It must always be remembered that they are part of an anastomosis necessary to life. Should they be very troublesome and incapacitate for work, they may be removed. In operating, strict aseptic methods must be practised, as septic lymphangitis readily occurs, and has frequently proved fatal after operations in such cases. Excision is not always satisfactory, as it may be followed by lymphorrhagia at the seat of the wound, by excessive dilatation of

some other part of the implicated lymphatic area, by chyluria, or by elephantiasis in one or both legs.

I have suggested that these tumours might be treated by establishing an anastomosis between one of the dilated lymphatic vessels and a neighbouring vein. Sir Rickman Godlee has twice performed such an operation for me with partial success: it is somewhat difficult, owing to the fragile nature of the dilated lymphatic vessels, and the shortness of their course.

It is said (Azema) that these glands tend to diminish in size after the age of 40. I cannot confirm this statement from personal observation.

Similar varicose dilatation of the axillary glands is sometimes, though much more rarely, found. Bancroft designated these varicose axillary and groin glands "helminthoma elastica."

Cutaneous and deeper lymphatic varices.—Occasionally cutaneous lymphatic varices are seen on the surface of the abdomen, on the legs, arms, and probably elsewhere. Sometimes they are permanent; sometimes, when more deeply situated, they constitute little swellings which come and go in a few hours. I believe these latter often depend on the actual presence of parent filariæ in the tumour. Such varices are evidence of lymphatic obstruction. Filarial lymphangiectasis of the spermatic cord is not uncommon. The contents may be milky and chylous, or straw-coloured and lymphous, according to situation and connections.

Thickened lymphatic trunks.—Maitland has frequently seen in Madras cases of lymphangitis in which, after the initial swelling and inflammation had subsided, a line of thickening remained. On excising this thickened tissue and carefully dissecting it, he has found minute cyst-like dilatations of the lymphatic involved, and in these cysts, coiled up, adult filariæ, sometimes dead, sometimes alive. The lymphangitis, he believes, is caused in these cases by the death of the filariæ. Daniels has made similar observations in British Guiana. Such a case I saw under the care of Dr. Abercrombie at Charing Cross Hospital in London. On the subsidence of a filarial lymphangitis of the arm a thickening, about the size

of a finger-tip, remained on the forearm. Believing that it contained adult filariæ, this thickening was excised by Mr. Young and placed in normal salt solution. Eight hours later the mass was carefully dissected, and a living female filaria, about 4 in.

Fig. 117.—Lymph scrotum and varicose groin glands. (*From a photograph by Dr. Rennie, Foochow.*)

in length, was turned out. The parasite continued to live and swim about actively in the salt solution for nearly two hours. Bahr has called attention to the frequency with which the epitrochlear gland is enlarged and thickened by filarial invasion.

Lymph scrotum (Fig. 117). *Symptoms.*—In this disease the scrotum is more or less enlarged.

Though usually silky to the touch, on inspection the skin presents a few, or a large number of, smaller or larger lymphatic varices which, when pricked or when they open spontaneously, discharge large quantities of milky, or sanguineous-looking, or straw-coloured, rapidly coagulating lymph or chyle. In some cases 8 or 10 oz. of this substance will escape from a puncture in the course of an hour or two; it may go on running for many hours on end, soiling the clothes of the patient and exhausting him. Usually microfilariæ can be discovered in the lymph so obtained, as well as in the blood of the patient. In a large proportion of cases of lymph scrotum the inguinal and femoral glands, either on one or on both sides, are varicose.

Probably provoked by friction against the thighs and clothes, erysipelatoid inflammation and elephantoid fever are frequent occurrences. Abscess is not uncommon. In time, in a proportion of cases, the scrotum tends to become permanently thickened and to pass into a state of true elephantiasis.

Treatment.—Unless inflammation be a frequent occurrence, or there be frequent and debilitating lymphorrhagia, or unless the disease tend to pass into true elephantiasis, lymph scrotum—kept scrupulously clean, powdered, suspended, and protected—had better be left alone. Should, however, for these or other reasons, it be deemed expedient to remove the diseased tissues, this can be effected easily. The scrotum should be well dragged down by an assistant whilst the testes are pushed up out of the way of injury. A finger knife is then passed through the scrotum, and in sound tissues, just clear of the testes, and the mass excised by cutting backwards and forwards. No diseased tissues, and hardly any flap, should be left. Sufficient covering for the testes can be got by dragging on and, if necessary, dissecting up the skin of the thighs, which readily yields and affords ample covering. It is a very common but a very great mistake to remove too little. As a rule, the wound, if carefully stitched and dressed antiseptically, heals rapidly.

In consequence of this violent interference with a large varix, of which that in the scrotum is but a part, chyluria, or elephantiasis of a leg, may supervene. The patient should be warned of this possibility.

Chyluria. *Pathology.*—When a lymphatic varix in the walls of the bladder, or elsewhere in the urinary tract, the consequence of filarial obstruction in the thoracic duct or in the lymphatics of the urinary system, ruptures, there is an escape of the contents of the lymphatics into the urine. Chyluria, or lymphuria, is the result.

Symptoms.—This disease frequently appears without warning; usually, however, pain in the back and aching sensations about the pelvis and groins—probably caused by great distension of the pre-existing lymphatic varix—precede it. Retention of urine, from the presence of chylous or lymphous coagula, is sometimes the first indication of serious trouble. Whether preceded by aching, or by retention, or by other symptoms, the patient becomes suddenly aware that he is passing milky urine. Sometimes, instead of being white, the urine is pinkish or even red; sometimes white in the morning, it is reddish in the evening, or vice versa. Sometimes, whilst chylous at one part of the day, it is perfectly limpid at another. Great variety in this respect exists in different cases, and even in the same case from time to time, depending on temporary closure of the rupture in the lymphatic, and also on the nature of the food.*

Physical characters of chylous urine.—If chylous urine be passed into a urine glass and allowed to stand, as a rule, within a very short time, the whole of the urine becomes coagulated. Gradually the coagulum contracts until, at the end of some hours, a small, more or less globular clot, usually bright red or pinkish in colour, is floating about in a milky fluid.

* The sanguineous appearance so frequently seen in chylous urine and in other forms of filarial lymphorrhagia probably depends in some instances on the formation of blood corpuscles in lymph long retained in the varicose vessels, and as a result of the normal evolution of the formed elements in that fluid; in other instances it is probably caused by rupture of small blood-vessels into the dilated lymphatics.

Later, the milky fluid separates into three layers. On the top there is formed a cream-like pellicle; at the bottom a scanty reddish sediment, sometimes including minute red clots; in the centre the mass of the urine forms a thick, intermediate stratum, milky white or reddish white in colour, in which floats the contracted coagulum. If a little of the sediment be taken up with a pipette and examined with the microscope, it is found to contain red blood-corpuscles, lymphocytes, granular fatty matter, epithelium, and urinary salts, and mixed with these in a large proportion of cases, though not in all, microfilariæ. The middle layer contains much granular fatty matter; whilst the upper cream-like layer consists of the same fatty material in greater abundance, the granules tending to aggregate into larger oil globules. If a little of the coagulum be teased out, pressed between two slides, and examined with the microscope, microfilariæ, more or less active, may be found in the meshes of the fibrin. If ether or xylol be shaken up with the milky urine, the fat particles are dissolved out and the urine becomes clear; the fat may be recovered by decanting and evaporating the ether which floats on the urine. Boiling the urine throws down a considerable precipitate of albumin. When the urine contains only lymph, fatty elements are absent, or are present in but very small amount.

Recovery and relapse.—Chyluria comes and goes in a very capricious manner. Sometimes the urine remains steadily chylous for weeks and months, and then suddenly, without obvious cause, becomes limpid and natural-looking, and free from fat or albumin. Later a relapse will occur, again to disappear after an uncertain time; and so on during a long course of years.

Retention of urine.—Retention of urine is not an unusual occurrence; it is produced by the formation of coagulum in the bladder. The retention usually gives way after a few hours of distress, worm-like clots being passed.

Constitutional effects.—Although chyluria is not directly dangerous to life, yet, being prolonged, it

gives rise to pronounced anæmia, with depression of spirits, and feelings of weakness and debility, and tends to incapacitate the patient for active, vigorous life.

Exciting causes of chyluria. — Chyluria is very liable to occur, either for the first time or as a relapse, in pregnancy or after childbirth; the disturbance of the pelvic lymphatics in pregnancy and the muscular efforts attending labour apparently causing rupture of pelvic lymphatics previously rendered varicose by filarial obstruction of the thoracic duct. In men, running, leaping, and violent efforts generally are sometimes assigned as its cause; usually the exciting cause is not discoverable.

Treatment.—The treatment of chyluria should be conducted on the same lines as the treatment of inaccessible varix elsewhere; that is to say, by resting and elevating the affected part, and thereby diminishing as far as possible the hydrostatic pressure in the distended vessels. Many forms of medicinal treatment have been advocated. Because during treatment with some drug a chyluria has subsided, curative properties are apt to be attributed to the drug. The best results are got by sending the patient to bed, elevating the pelvis, restricting the amount of food and fluid—especially fatty food—gentle purgation, and absolute rest. It will be found that a day or two of treatment on these lines is often followed by temporary, perhaps prolonged, cessation of the chyluria. The drugs which have been particularly lauded in the treatment of this disease are gallic acid in large doses, benzoic acid in large doses, glycerine, the tincture of the perchloride of iron, decoction of mangrove bark, chromic acid, quinine, salicylate of soda, ichthyol, and *Nigella sativa.* I do not believe that these substances have any influence whatever in stopping the lymphorrhagia. Neither do I believe that thymol, recommended by Lawrie, or methylene blue, recommended by American writers, has any effect either on the filaria or on the disease it gives rise to; since their first recommendation both drugs have been tried, but in other hands have failed.

Filarial orchitis. — Several French writers describe under the name "malarial orchitis" a special form of inflammation of the testes, and here and there in Indian medical literature allusion is made to the same or a similar subject. I have many times seen filarial orchitis, but I cannot say I have seen orchitis of purely and unquestionably malarial origin. The fever attending filarial orchitis—which is usually associated with lymphangitis of the spermatic cord (funiculitis) and perhaps with inflammation of the scrotum—like ordinary elephantoid fever resembles very closely a malarial attack, and may be mistaken for this. Without absolutely denying the existence of such a disease as malarial orchitis, I would suggest that the affection described by the French and Indian writers referred to, and endemic inflammations of testes, spermatic cords, and scrotum generally, are of filarial origin.

Filarial synovitis.—Maitland mentions acute synovitis of the knee-joint as one of the filarial diseases, and gives the particulars of five cases. He considers the concurrence of synovitis with filarial invasion too common to be accidental. Bahr has confirmed this, and has found that ankylosis often results. In cases where the hip-joint is affected, removal of the inflamed iliac glands draining the area appears to relieve the condition.

ELEPHANTIASIS

Its prevalence.—Elephantiasis is by far the most frequent manifestation of filarial invasion, and is exceedingly common in some of the endemic districts. Thus, in certain districts in Cochin about 5 per cent. of the population, in Samoa about every second individual, in Huahine seven-tenths of the adult male population are affected. In many other tropical and sub-tropical countries, if not so common as in those just mentioned, elephantiasis is, nevertheless, common enough.

Parts affected.—In 95 per cent. of the cases the lower extremities—either one or both—alone, or in combination with the scrotum or arms, are the seat of

the disease. The foot and ankle only, or the foot and leg, or the foot, leg, and thigh, may, each or all, be involved. The scrotum is also a common situation for elephantiasis. The arms are more rarely attacked; still more rarely the mammæ, vulva, and circumscribed portions of the integuments of the limbs, trunk, neck, or scalp (Fig. 118).

The recurring erysipelatoid attacks.—The disease in any of these situations commences with a rapidly evolved lymphangitis, dermatitis, and cellulitis accompanied by elephantoid fever. On the subsidence of the acute symptoms the skin and subcutaneous fascia of the affected part do not quite resume their original proportions; the inflammatory effusion not being completely absorbed, some permanent thickening remains. Recurrences of this inflammation once or twice a month, or perhaps once in six months, or every twelve months, or even at longer intervals, add a little each time to the bulk of the limb or scrotum. Thus, gradually, an enormous swelling may be built up. Occasionally, though very rarely, enlargement may progress after one, two, or more initial inflammatory attacks, and without further recurrence of these.

Fig. 118.—Elephantiasis of scalp. (*Journ. of Trop. Med.*)

Clinical characters of the swelling.—The affected part is greatly increased in bulk. The surface of the skin, in confirmed elephantiasis especially, is rough and coarse; the mouths of the follicles are sometimes unusually distinct; the papillæ and glands are either hypertrophied or atrophied; the hair is coarse and sparse; the nails are rough, thick, and deformed. Around joints the thickened integuments are thrown into folds, the comparatively smooth-sided and deep

interlying sulci permitting limited movement. There is no distinct line of demarcation between healthy and diseased skin. The implicated integuments are hard, dense, pit but slightly if at all on pressure, and cannot be pinched up or freely glided over the deeper parts.

Its macroscopic anatomy.—On cutting into the swelling, the derma is found to be dense, fibrous, and enormously hypertrophied. The subjacent connective tissue is increased in bulk, having, especially in the case of the scrotum, a yellowish, blubbery appearance from lymphous infiltration. A large quantity of fluid wells out on division of such tissues. The muscles, nerves, and bones are not necessarily diseased, although in rare instances they may be degenerated and slightly or considerably atrophied from pressure. The blood-vessels are large; the lymphatics dilated; the associated lymphatic glands, both of the same side and, very often, of the opposite side, enlarged and dense.

True elephantiasis permanent.—Though in recent cases the bulk of the limbs may be much reduced temporarily by treatment, the disease is never permanently recovered from. Simple lymphatic œdema in areas which have never become inflamed subsides readily enough on pressure or elevation.

Elephantiasis of the legs (Fig. 119).—Elephantiasis of the lower extremities is usually, though by no means always, confined to below the knee. The swelling may attain enormous dimensions and involve the entire extremity, the leg or legs attaining a circumference, in aggravated cases, of several feet.

Treatment.—In the treatment of elephantiasis of the leg the patient should be encouraged to persevere with elastic bandaging, massage, and elevation of the limb. Castellani claims good results from a combination of these measures with daily injections of fibrolysin 2 c.c. Ligature of the femoral artery has been practised; it is probably useless, and is certainly not a justifiable method of treatment. Sometimes, in extreme cases, good results are got from excision of redundant masses of skin, a longitudinal strip of three or four inches in breadth by a foot or more in

length being dissected off. Charles advocates complete resection of the whole of the elephantoid tissue except the sole of the foot, followed by extensive skin-grafting. Electrolysis and mercury have also been used; I question their value. During the acute attacks, tension may be relieved by aseptic punctures with a sharp lancet. At all times the limb must

Fig. 119.—Elephantiasis of legs; scrotum and right arm also affected. (*From a photograph by Dr. Turner, Samoa.*)

be carefully guarded from injury, and shoes and trousers worn. Slight injuries provoke the inflammatory recurrences. Wading in water, prolonged standing, violent exercise, and exposure to a hot sun are injurious and should be avoided.

Handley has brought forward an operation, lymphangioplasty, the underlying principle of which is the drainage of an area of lymph stasis into an adjacent patent lymphatic area by means of strands

of silk passing from one to the other. He describes the operation thus: "Eight stout silk threads were led upwards from the foot to a point in the iliac fossa just above Poupart's ligament. These were spaced out round the limb at intervals. Above they united to form a leash. The iliacus muscle was exposed by a short incision like that for ligature of the external iliac artery. Half the threads were passed through a portion of the iliacus muscle, and were knotted in pairs to the other four threads, thus fixing them securely to the tissues of the iliac fossa. The multiple small incisions through which the threads were introduced were closed by horsehair sutures, leaving the silk completely buried in the subcutaneous tissues." He claims a comparative success in one marked case of elephantiasis of the leg. Judging from the narrative of this case (*Trans. Soc. of Trop. Med.*, vol. ii., p. 41) the operation is attended with considerable risk from sepsis. Others who have practised it do not report favourably on the results.

Lanz's operation aims at deep lymphatic drainage. A longitudinal incision is made through the fascia lata down to the femur, the periosteum of which is stripped and the bone trephined in several places; strips of fascia are then inserted into the openings thus made. Surgeons who have followed this method report excellent results; many have omitted trephining the bone and have contented themselves with incising the fascia lata.

Kondoleon's operation consists also of free incision of the fascia lata and removal of large sections of the aponeurosis; the removal of this tissue assists in the anastomosis of lymph channels and veins. This operation has been favourably reported on by Matas.

Elephantiasis of the scrotum (Fig. 120). *Weight of tumours.*—Elephantiasis of the scrotum, or "scrotal tumour" as it is sometimes called, may attain an enormous size: 10, 15, or 20 lb. are common weights for these tumours, and 40 or 50 lb. is by no means uncommon. The largest recorded weighed 224 lb.

integuments, elephantoid fever, which before may have been frequent, ceases to recur.

Treatment preliminary to operation. — If the tumour is of considerable size, the patient should keep his bed for a day or two before operation, the mass being suspended so as to drain it of fluid and blood. It is thus rendered lax, and the operator is enabled to ascertain by palpation the position of the testes and, if such chance to be present, of hernia—a not very unusual complication. The possibility of undescended testes should not be overlooked.

Operation.—Before making provision for the prevention of hæmorrhage the operator should mark out by shallow cuts the line at which he proposes to separate the tumour, care being taken that these guiding incisions run through and include only absolutely sound skin. If the latter precaution be neglected, disease is very liable to recur in the scar or flaps. First, the tumour is turned up and a shallow transverse cut is drawn in sound skin across the perineum in front of the anus. The tumour being allowed to fall down, a similar shallow cut is made across the pubes. The corresponding extremities of these two cuts are then united either by a straight cut, or, if there be a little sound skin on the thigh aspects of the tumour, by semilunar incisions.

Assistants then firmly draw down the scrotum as far as possible, and the surgeon, if he deem it desirable, applies elastic webbing over the mass so as to expel the blood it contains. Next, a stout rubber cord is wound, figure-of-eight fashion, round the neck of the tumour, well above the guiding incisions, and over the pelvis, and firmly secured (MacLeod) (Fig. 122). Or the rubber cord is wound round the neck of the tumour only, being kept in place by four strips of bandage passing under this cord, one on each side of the scrotum before and behind, and firmly tied over another strip of bandage encircling the waist.

The testes and spermatic cords are first dissected out through long perpendicular incisions made in front, the remains of the gubernacula testes being hooked up with the finger and snipped through with scissors. The

channel of the prepuce is next slit up, the incision being carried up to the pubic limiting mark. The penis can then be shelled out, the prepuce being first cut through around the corona glandis. If lateral flaps can be formed of sound skin they are then dissected up. The perineal and pubic incisions are now deepened and, assistants holding the testes and penis well out of the way, the neck of the tumour is cut through close to the perineum and pubes. Gaping vessels are all carefully ligatured, redundant tunica vaginalis—if hydroceles be present—being excised. The rubber cord is then removed.

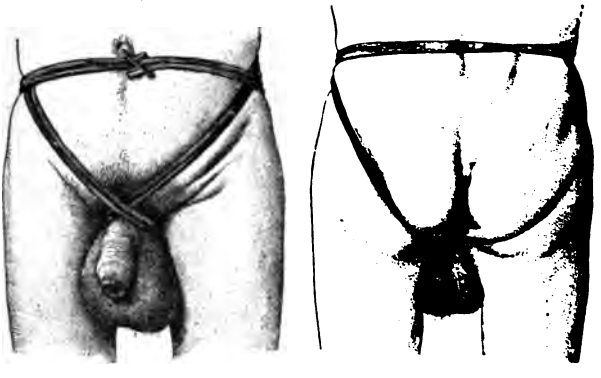


Fig. 122.—Rubber cord in position. (*MacLeod.*)

When hæmorrhage has been controlled, the posterior halves of the flaps are brought together by sutures, the anterior halves being united over the testes to the pubic cut. The penis will therefore emerge from the point where the horizontal line meets the perpendicular line of what is now a T- or Y-shaped wound. If no flaps have been made, the testes may be fixed by stitching any tag of tissue connected with them to the perineum, and the dimensions of the wound reduced as much as possible by stitching up the corners at the pubes and perineum.

In dressing it is of importance that the raw surfaces be covered by some aseptic *non-fibrous* protective—such as oiled silk—before the antiseptic dressing is

applied. A fibrous dressing next the raw surfaces is troublesome, as it sticks to the wound and is painful and difficult to remove. The dressing should be massive, well padded, and kept in place by an eight-tailed bandage secured in front and behind to a strap round the waist, a hole being cut in front for the penis to emerge. The large wound generally does well. Skin grafting should be practised freely and early, especially round the root of the penis.

Mortality from operation.—The mortality from these formidable-looking operations, if they are care-

Fig. 123.—Elephantiasis of labia majora. (*After Nuñez.*)

fully done, is small, and need not exceed 5 per cent. The results are very satisfactory, as a rule, the functions of the organs being retained or restored.

Elephantiasis of the arms.—This is comparatively rare. Allowing for the differences between the upper and lower extremities as regards gravitation of fluids, the symptoms and pathology of elephantiasis of the arm are the same as those of elephantiasis of the legs. Beyond the judicious employment of massage and elastic bandaging, little can be done in the way of treatment.

Elephantiasis of the vulva and mammæ. — Elephantiasis of the vulva (Figs. 123, 124) and mammæ (Fig. 125) is still rarer. Where growth has

Fig. 124.—Elephantiasis of vulva. (*From a photograph by Dr. Walter H. B. Macdonald.*)

Fig. 125.—Elephantiasis of mammæ; left leg and foot also affected.
(*From a photograph by Dr. Davies, Samoa.*)

become inconveniently large the diseased tissues should be removed. Instances are on record in which the integuments of the mammæ have become so thickened, heavy, and elongated that the organ has descended to the pubes and even to the knee. One such tumour weighed 21 lb. after removal. Tumours of the labia or of the clitoris, similarly, may attain a great size—8 or 10 lb., or even more.

Fig. 126.—Pedunculated groin elephantiasis. (*From a photograph by Dr. Daniels.*)

Elephantiasis of limited skin areas.—Corney states that pedunculated elephantoid tumours, springing from the groin or from the anterior surface of the thigh, are not uncommon in Fiji. One such tumour which he removed weighed 20 lb. Daniels has seen, both in Fiji and in Demerara, several cases of this description (Fig. 126). Silcock describes a pedunculated tumour of this nature that

he removed from the neck of an East Indian, and which weighed, after removal, 30 lb. I have often seen limited areas of elephantoid thickening of the skin, particularly on the thighs. These conditions are easily dealt with by simple operations.

Chylous dropsy of the tunica vaginalis, and of the peritoneum; chylous diarrhœa.—Chylous dropsy of the tunica vaginalis is not an unusual occurrence in the tropics. A fluctuating swelling of the tunica vaginalis, which does not transmit light, and which is associated possibly with lymph scrotum, with varicose groin glands, with chyluria, or with microfilariæ in the blood, would suggesta diagnosis of this condition. These collections of chylous fluid in the tunica vaginalis generally contain enormous numbers of microfilariæ. Large numbers of cretified adult filariæ have been found in the thickened tunica vaginalis and in the epididymis in this condition.

These chyloceles may be treated as ordinary hydroceles, either by aseptic incision or by injection.

Filarial orchitis with effusion into the tunica vaginalis, according to Maitland, is best treated by incision of the tunica vaginalis, turning out any clot that may be found in the sac, and stuffing the latter with iodoform gauze. This procedure, he says, gives immediate relief.

Chylous dropsy of the peritoneum and chylous diarrhœa of filarial origin are very rare.

Prophylaxis of filarial disease.—The prevention of filarial disease resolves itself into anti-mosquito measures and protection from mosquito bite. With this in view, unprotected wells, tanks, or stagnant pools must not be permitted in the neighbourhood of dwelling-houses. The influence of these in spreading filarial disease has been ably demonstrated by Daniels in Demerara, and by Low in Barbados. All vessels used for storing water should be emptied at least once a week. The mosquito net is indispensable in filarial as well as in malarial countries.

The subjects of filariasis should be regarded as dangers to themselves and to the community and be compelled to sleep under mosquito nets.

FILARIA PERSTANS, Manson, 1891. (Plate X., Fig. 2.)

Synonym.—*Acanthocheilonema perstans*, Railliet, Henry, and Langeron, 1912.

Geographical range.—This parasite is very common in the blood of the natives of large districts in tropical Africa. I have found it in natives from Old Calabar and from the basin of the Congo—both in the coast negroes and in those from the interior. Annett, Dutton, and Elliott report its presence in many places in Southern Nigeria, in Northern Nigeria, in Lagos, in the Gold and Ivory Coasts, in the Kroo Coast, and in Sierra Leone. In Northern Rhodesia it is very common; I found it in 30 per cent. of a number of the natives I examined recently. On the Congo in parts it occurs in half the population. Prof. Firket, of Liége, has confirmed this observation as regards the Congo district. Cook, Hodges, and Low have found the parasite to be extremely common in Uganda, where, in some districts, Low has found it in 90 per cent. of the population. Sometimes it occurs along with *mf. loa*, *mf. bancrofti*, and, in British Guiana, as stated, with *mf. ozzardi*, in the same individual. I have never found it in West Indian negroes, nor, in fact, in natives of any country except those of tropical Africa, and in the aborigines of Demerara. I have frequently found it in Europeans who had resided on the Congo.

Fig. 127.—Tail of adult F. perstans.

Its characters.—*Microfilaria perstans* observes no periodicity, being present in the blood both by day and by night. In this respect it resembles *mf. demarquaii* and *mf. ozzardi*; and, like these, in size, shape, and anatomical detail it differs very materially from *mf. bancrofti* and *mf. loa*. The number of microfilariæ in the peripheral circulation may vary considerably, but there is no marked difference between day and night. Their special seat of selection is not the peripheral blood, but that of the heart, lungs, aorta and other large vessels. They have not been found in the spleen, and only rarely in the liver and pancreas.

The larva in the blood measures, on an average, 0·2 mm.

in length by 0·0045 mm. in breadth; but, as it possesses in a remarkable degree the power to elongate and to shorten itself, these measurements do not always apply. It is manifestly much smaller than *mf. bancrofti* and *mf. loa*, and is further distinguished from these microfilariæ by the entire absence of a sheath, and by the characters of its caudal end, which is invariably truncated and abruptly rounded off. The taper which terminates in the tail extends through quite two-thirds of the entire length of the animal. Further, if the head be carefully observed with a high power, a fang can generally be easily seen—much more easily than the corresponding structure in *mf. bancrofti*—in constant play, shot out and retracted. The V spot is about 0·03 mm. from the cephalic extremity. There is no marked tail spot. No hooked cephalic prepuce can be made out. According to Fülleborn, no red staining "granular mass" can be demonstrated as in the case of *mf. bancrofti* and *mf. loa*. Its movements also differ from those of *mf. bancrofti*, for it not only wriggles about, just as that parasite does, but it indulges in long excursions through the blood, moving freely all over the slide, locomoting in fact very much in the same way as *mf. bancrofti* does in the mosquito's stomach after it has cast its sheath.

Adult form.—The adult form, discovered by Daniels in Demerara Indians, and subsequently identified by myself as that of *F. perstans*, is, like *F. bancrofti*, a long, cylindrical, filiform nematode. The body is smooth, without markings; the mouth simple and unarmed. The tail in both sexes is peculiar and characteristic; it is incurvated, and the chitinous covering at the extreme tip is split up as it were into two minute triangular appendages, giving it a mitred appearance (Fig. 127). The adult female measures 70 to 80 mm. in length by 0·12 mm. in breadth. The head is club-shaped and measures 0·07 mm. in diameter. The genital pore opens at 0·6 mm. from the head. The anus opens at the apex of a papilla situated in the concavity of the curve formed by the tail. The diameter of the tail just before termination is 0·02 mm. The male is smaller than the female; it measures 45 mm. in length by 0·06 mm. in breadth. The diameter of the head is 0·04 mm. Close to the opening of the cloaca there are four pairs of preanal and one pair of postanal papillæ, and, according to Leiper, another small pair are situated midway between these groups. Two unequal spicules may sometimes be seen protruding from the cloaca. So far the adult forms have been found only in the connective tissues at the root of the mesentery, behind the abdominal aorta, and beneath the pericardium.

Life history.—Very little is known of the life history of *F. perstans*. Although it has a wide geographical range, this filaria appears to be limited in its topography to areas covered by dense forest growth and abounding in swamps. In Kavirondo, where the forest disappears and the land is covered with scrub and short grass, it is not found; likewise it

is not found on the grassy plains of the highlands of British East Africa. Towns and cultivated areas are free from it. This peculiar limitation of its distribution would indicate an intermediary restricted to similar stations, certain Tabanidæ, for instance, or certain species of sylvan mosquitoes. In order to find the intermediary host of *F. perstans*, Low made numerous experiments with many different species of mosquitoes (*Culex fatigans*, *C. atratus*, *C. viridus*, *C. luteolateralis*, *C. quasigelidus*; *Anopheles argyrotarsis*, *A. costalis*, *A. funestus*; *Stethomyia nimbus*; *Zanthinosoma musica*; *Mansonia africana*; *Uranotænia cæruleocephala*; *Tæniorhynchus fuscopennatus*) and other blood-sucking insects (*Pulex irritans*, *Sarcopsylla penetrans*, *Pediculus capitis*, and *P. vestimentorum*). These insects were either caught in the huts of infected persons or were reared from the larva and then fed on infected persons. After a certain time they were dissected, but, with one exception, the results were negative. In one isolated instance two developmental forms were seen between the thoracic muscles of a *Tæniorhynchus fuscopennatus* reared from the larva and fed on infected persons. Fülleborn has found similar developmental forms once in *An. maculipennis*. Christy suggests that the true intermediary host of *F. perstans* is *Ornithodoros moubata*, a tick of the sub-family *Argasinæ*. He gives no evidence in support of this view, which is contradicted by the facts of geographical and topographical distribution.

Pathology.—So far as known, *F. perstans* has no great pathological importance; the presence of the adult parasites in the mesentery appears to cause little harm to the host.

MICROFILARIA DEMARQUAII, Manson, 1895. (Plate X., Fig. 4.)

In examining blood sent me by Dr. Newsam from natives of St. Vincent, West Indies, I found this microfilaria in several individuals—in 10 out of 152 examined. It resembled *mf. bancrofti* and *mf. loa* so far as shape is concerned, but differed from them in size, its average measurements being, according to Low, 0·2 mm. by 0·005 mm. It is sharp-tailed, has no sheath, and observes no periodicity, being present in the peripheral circulation both by day and by night. Its movements are very active; it can shorten or elongate itself, and not only wriggle about very actively, but travel from place to place on the fresh blood slide. Nothing is known of its life history or pathological bearings.

I have met with the same parasite in the blood of natives of St. Lucia, W.I., an observation confirmed by Galgey, Low, and St. George Gray. Low has also found it in the blood of natives of Dominica and Trinidad. Usually some eight or ten parasites are found in a preparation of ordinary dimensions; occasionally instances of high degrees of infection are met with, in which hundreds of microfilariæ can be counted on every slide. Its topographical distribution is singularly circumscribed, even in the endemic districts.

Galgey found five adult female filariæ in the omental tissues of a patient in whose blood *mf. demarquaii* had been discovered during life. No male was found.

These worms closely resembled the adult *F. ozzardi*, but, according to Daniels, exhibited structural differences, especially as regards the shape of the head and tail, which led him to conclude that they are specifically distinct. They measured from 65–80 mm. in length by 0·21–0·25 mm. in breadth. The head has a diameter of from 0·09 to 0·1 mm. The mouth is terminal. The genital pore opens at 0·76 mm. from the head. The alimentary canal is nearly straight, and terminates in an anus which is subterminal. The opening of the anus is marked by a slight papilla. The tail is curved and rapidly diminishes in size just below the anal papilla. A marked cuticular thickening covers the tip of the tail. The diameter near the tip of the tail, before its termination, is 0·03 mm. *F. demarquaii* is a thicker worm than *F. perstans*. It differs from *F. bancrofti* and *F. ozzardi* in the greater size of the head, in the smaller tail, and particularly in the marked cuticular thickening at the tip of the tail. This thickening is knobby and bifid, but the divisions are not so well marked as in *F. perstans*. The intermediate host has not been discovered. Low believes it to be a rare species of mosquito. It is quite possible that some of the minute, sharp-tailed filariæ (*F. ozzardi*) of British Guiana are the same species.

I have also found a minute, non-sheathed, sharp-tailed microfilaria, closely resembling *mf. demarquaii*, in the blood of natives of New Guinea. Whether these various minute, sharp-tailed, non-sheathed embryos belong to one or to several species it is impossible to decide until the adult forms of each have been discovered and carefully compared.

Filaria ozzardi, Manson, 1897.

Some years ago I received from Dr. Ozzard, British Guiana, a number of blood films prepared from aboriginal Carib Indians inhabiting the back-country of that colony. Although the negroes and other inhabitants of the littoral and settled districts of British Guiana are very subject to *F. bancrofti* and to elephantiasis, in none of the considerable number of slides of Carib blood from time to time received from Drs. Ozzard and Daniels have I once encountered *mf. bancrofti*. Daniels records an identical experience. I am assured by Dr. Ozzard that elephantiasis is unknown amongst these people. On examining the blood slides referred to, I discovered certain nematode larvæ with characters so peculiar that I suspected they represented at least one new species of blood worm, which I called, provisionally, *F. ozzardi*. At least half the slides examined contained these parasites, some slides only one or two, other slides as many as forty or fifty.

In size and shape five out of six of the embryos resembled very closely *mf. perstans* (p. 722)—that is to say, they were blunt-tailed, had no sheath, and were very minute (0·173 to

0·240 mm. by 0·0043 to 0·005 mm., Daniels). But along with the blunt-tailed filariæ, and on the same slides, there occurred a sharp-tailed form, also very minute, and resembling *mf. demarquaii*. Drs. Ozzard and Daniels confirmed this discovery. Both of these observers have had abundant opportunity of examining these microfilariæ alive. They found that both the sharp-tailed and the blunt-tailed worms behave in fresh blood on the microscope slide much in the same way that *mf. perstans* and *mf. demarquaii* do; that is, they wriggle about very actively, at the same time retracting, elongating, and locomoting in the blood.

Parental form.—For a time the relationship of these microfilariæ, both to each other and to *mf. demarquaii*, remained undetermined. Later Daniels found parental filariæ—male and female—at the post-mortem examinations of two Demerara Indians whose blood, during life, contained both blunt- and sharp-tailed larvæ. The mature worms, apparently numerous, were about 3 in. in length and very slender—about one-half the diameter of *F. bancrofti*. They were, therefore, not *F. magalhães*i (p. 728). The head was somewhat club-shaped and showed no papillæ. The tail of the male was much coiled, and carried at least one long protruding spicule. These worms were found in one case in the mesentery and in the fat at the base of the mesentery; in the other "not only in mesentery and abdominal fat, but also in the subpericardial fat." The embryos in utero, Daniels stated, were all blunt-tailed. I had an opportunity of comparing these worms with unquestionable adult *F. perstans*. I found them to be identical. The peculiar bifid arrangement of the termination of the tail was quite characteristic of that parasite (p. 723).

Later, Daniels found at the post-mortem examination of a third aboriginal, in whose blood both the blunt-tailed (*F. perstans*) and the sharp-tailed microfilariæ had been found (and no others), a few adult *F. perstans* and, in addition, a female and portion of a male worm of quite a different species—presumably the parental form of the sharp-tailed larvæ. The two latter adult worms lay close together, and were believed to have been located in the subperitoneal connective tissues in the anterior abdominal wall. Except in the matter of the caudal extremity, which was slightly bulbous and without cuticular thickening, in size and structure they closely resembled *F. bancrofti*. Daniels has drawn up a table (p. 728) of the leading dimensions of the three species—*F. bancrofti*, *F. perstans*, and of this possibly new filaria for which I propose to retain provisionally the name *F. ozzardi*.* (Fig. 128.)

* It now seems probable that there is but one species, *F. demarquaii*. In this event the latter name, in conformity with the rules of nomenclature, will have to be dropped, and therefore *F. demarquaii* will henceforth be called *F. ozzardi*. This statement has lately been confirmed by Leiper, who affirms that the recorded adults of *Filaria ozzardi* (as distinguished from the adults of *F. demarquaii*) are undoubtedy specimens of *F. bancrofti*.

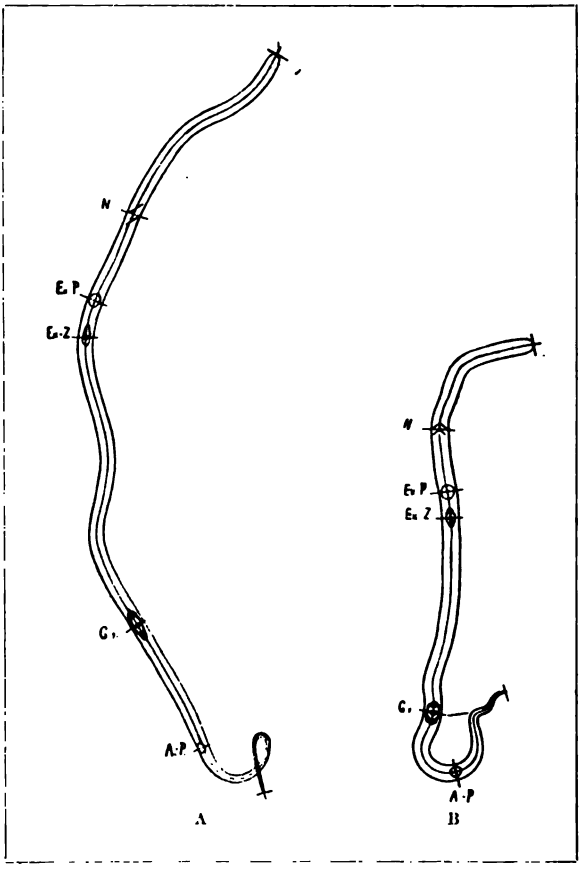


Fig. 128.—A, Scheme for the measurement of certain fixed points of structure in microfilariæ, of value in the diagnosis of species. B shows that even in a shrunken specimen the measurements retain their same proportionate value. (*After Fülleborn.*)

Measurements: 1, From the ant. extremity to the nerve ring (N.); 2, to the middle of the excretory pore (Ex.P.); 3, to the nucleolus of the excretory cell (Ex.Z.); 4, to the nucleolus of the genital cell (G.1); 5, to the middle of the anal pore (A.P.); 6, to the terminal tail nucleus.

TABLE OF LEADING DIMENSIONS OF FILARIÆ

	FILARIA BANCROFTI	FILARIA PERSTANS	FILARIA OZZARDI
	Mm.	Mm.	Mm.
Length	85 to 90	70 to 80	81
Greatest thickness ...	0·20 to 0·26	0·120	0·210
Diameter of head	0·055	0·070	0·050
Diameter of neck	0·049	0·054	0·039
Distance from head—			
(1) Of vaginal outlet ...	0·710	0·600	0·710
(2) Of ovarian opening ...	0·920	?	0·850
Distance from tail of anal papilla	0·225	0·145	0·230
Termination of tail ...	Blunt, circular, not bulbous.	Slightly bulbous; covered by thickened cuticle prolonged into two triangular appendages.	Bulbous cuticle not thickened.

FILARIA MAGALHÃESI, R. Blanch., 1895.

Professor Magalhães describes two sexually mature filarial hæmatozoa, male and female, which were found lying in the left ventricle of the heart of a child in Rio de Janeiro. No information was received as to the nature of the disease of which the child died, nor had any examination of the blood been made during life. The parasites were cylindrical, capillary, opalescent, white, uniform in thickness except where the body tapered towards the tail and at the club-shaped oral end. The mouth was simple, circular, unarmed; the cuticle marked with fine transverse striations. The female worm measured 155 mm. in length by 0·7 mm. in diameter, the male 83 mm. in length by 0·4 mm. in diameter. The tail of the latter was provided with four pairs of preanal and four pairs of postanal papillæ, and two spicules. Manifestly this parasite is specifically distinct from *F. bancrofti* and the other blood worms described above. Nothing is known of its life history, nor of the associated pathology.

CHAPTER XLI

I. PARASITES OF THE CIRCULATORY AND LYMPHATIC SYSTEMS (*concluded*)

SCHISTOSOMUM HÆMATOBIUM (Bilh.-v. Sieb. 1852)

Definition.—A chronic, endemic disease caused by *Schistosomum hæmatobium* (=*Bilharzia hæmatobia*, *Distomum hæmatobium*), giving rise to cystitis and hæmaturia, or to proctitis, or to other symptoms, and characterized by the presence of the ova of that parasite in the urine, or in the fæces, or in both.

History and geographical distribution.—The frequency of hæmaturia in the natives of Egypt, and in visitors to that country, has long been remarked. The explanation of this peculiar circumstance was supplied by Bilharz who, in 1851, discovered the cause in a peculiar trematode which Cobbold proposed to name *Bilharzia*, in honour of its discoverer.

In 1864 Dr. John Harley recognized the characteristic ova in cases of hæmaturia from Natal. The disease has since been found in many other parts of Africa, more particularly along the eastern side of the continent as far south as Port Elizabeth. Balfour found it in the Soudan. According to Low it is very frequent in the natives of Uganda. It is very common in Rhodesia. In Egypt, judging from Bilharz's, Griesinger's, and Sonsino's post-mortem records, it is present in quite one-half of the population. It occurs also in Arabia, Syria, Persia, Mesopotamia, Cyprus, and Mauritius. Nelson has recorded recently the occurrence of two cases in Western Australia in individuals who had never been out of that country; apparently the parasite was introduced by a man who had served as a soldier in the Boer War.

Etiology.—*Schistosomum hæmatobium* (Figs. 129, 130, 131) is a bisexual trematode belonging to the family *Schistosomidæ*. The *male* is white, cylindroid, 11 to 15 mm. in length by 1 mm. in breadth. It possesses an oral and a ventral sucker of about equal size and placed close together. The cylindrical appearance of the worm is produced by the ventral infolding of the two sides of what would otherwise be a flat body. By this infolding a gynæcophoric canal is formed, in which the female can be partially enclosed. The outer surface of the body is closely beset with small cuticular prominences. The *female* is rather darker in colour than the male, considerably longer (20 mm.), more filiform, her middle being usually infolded in the gynæcophoric canal referred to, whilst her anterior and posterior portions remain free. The genital openings of the sexes face each other, and are placed immediately posterior to the ventral sucker. The sexes live apart while young, but on reaching maturity the female enters the gynæcophoric canal of the male.

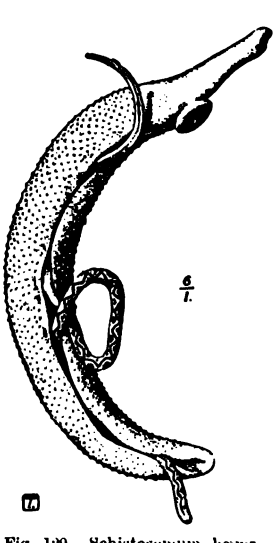


Fig. 129.—Schistosomum hæmatobium, male and female. (*Partly after Looss.*)

These parasites are found in the blood of the portal vein, in its mesenteric and splenic branches, and in the vesical, uterine, and hæmorrhoidal veins. They have also been found in the vena cava; Sonsino considers that, if searched for, they would probably be found elsewhere in the circulation. Their numbers vary considerably. Sonsino reports finding in one case forty; in another case Kartulis found 300 in the portal vein and its branches. Looss has seen the submucous tissue of the bladder so rich in worms that a pair could be found in every area of half a centimetre square.

The ovum.—On microscopical examination the uterus of the female bilharzia is found to be stuffed with ova of a peculiar and characteristic shape. They are oval, each egg on an average measuring about 0·16 mm. in length by 0·06 mm. in breadth, and one end of the ovum is provided with a short, stout, and very definite spine. (Plate XIII., Fig. 1.)

The exact nature of the process by which the ova leave the body of the human host has not been satisfactorily explained.

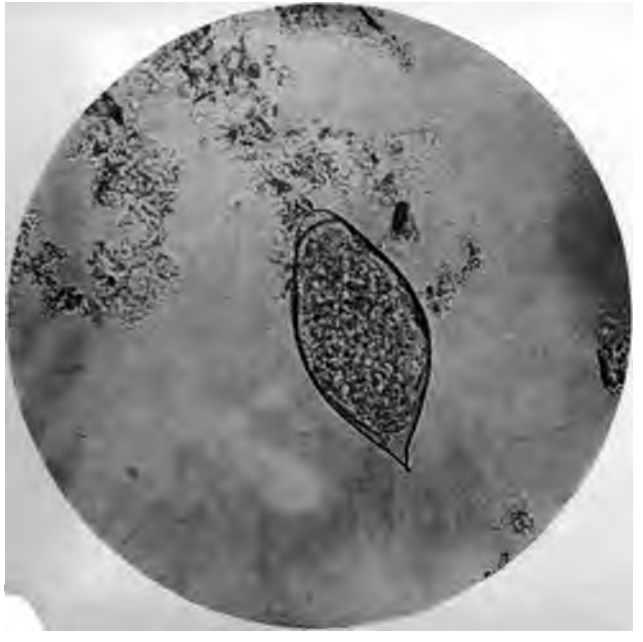


Fig. 1.—Terminal-spined egg of Schistosomum hæmatobium.
(*Microphoto: Dr. Bell.*)

Fig. 2.—Lateral-spined egg of Schistosomum mansoni.
(*Microphoto: Dr. Kerr.*)

PLATE XIII.

Apparently the female worm migrates from time to time from the larger veins to their smaller radicles, and in these deposits her ova. The walls of the bladder are the favourite situations for this purpose. Afterwards the eggs are somehow carried, possibly aided by the spine with which they are provided, towards the surface of the mucous membrane, and then, falling into the bladder, are voided with the urine, a certain amount of blood escaping at the same time.

The free larva (Fig. 132).—In newly voided urine the ovum presents a somewhat brownish appearance, and generally contains a ciliated larva (*miracidium*). After a time the larva may escape through a longitudinal rupture in the shell. It then swims about, but, unless supplied with fresh water, soon perishes. If the urine be freely diluted with water, the larva not only escapes more quickly from the shell but also continues to live, swimming and gyrating very actively for a

Fig. 130.—Schistosomum hæmatobium; anterior end of male. (*After Looss.*)

Fig. 131.—Schistosomum hæmatobium. Diagram of transverse section of male and female.

considerable time. While swimming, the body of the little animal undergoes many changes of shape. For the most part, when advancing, it is oblong, tapering somewhat posteriorly; when more stationary it tends to assume a spherical form. It moves by means of the cilia which, with the exception of the minute papillary beak, thickly cover the entire body. On carefully examining the larva, a canal may be traced from the beak into what looks like a rudimentary stomach; on both sides of this two much smaller gland-like organs can be seen, from each of which a delicate tube passes forwards and opens, apparently, somewhere in the neighbourhood of the beak. The bulk of the larva is occupied by a number of sarcode globules. A careful description of the miracidium is given by Brock (*Lancet*, Sept. 9, 1893, p. 625) to which the reader is referred for further details.

Life history.—Beyond its first stage of free-swimming ciliated larva, the extracorporeal life of schistosomum is quite unknown, notwithstanding the many attempts that have been

made to trace its future progress. Sonsino believed at one time that he had discovered its intermediate host in a fresh-water arthropod; this view he afterwards abandoned. Analogy suggests that the miracidium passes into the body of some fresh-water mollusc, crustacean, or larval arthropod, there to undergo the developmental changes into the redia and possibly the cercaria stages usually exhibited by the trematodes. Later, it may become encysted, and then, either free or still in the body of the intermediate host, gain access to man by penetrating the skin or through the stomach, and so pass to the veins of the portal system. Miracidia under experimental conditions live thirty to forty hours in water and are killed by very dilute solutions of HCl. Looss has expressed the opinion that, unlike other trematodes, *Schistosomum hæmatobium* does not require the services of an intermediary host, and that the miracidium enters the human body directly by penetrating the skin. The natives of some parts of Africa believe that endemic hæmaturia is acquired in bathing, the parasite entering the body by the urethra, and, in consequence, they employ various mechanical devices to prevent such a calamity. I would remark that if *S. hæmatobium* does not require the services of an intermediary host its peculiar geographical limitations are difficult to explain. Further, the fact that it can spread in Australia suggests that the intermediary is some organism common to that continent and to Africa.

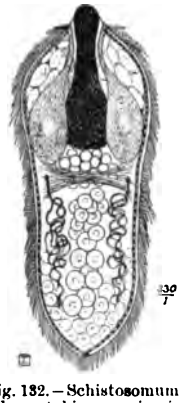


Fig. 132.—Schistosomum hæmatobium miracidium. (*After Looss.*)

Symptoms.—The symptoms produced by schistosomum vary in degree within very wide limits. In the vast majority of instances the patient experiences no trouble whatever; in other instances the suffering is very great. Indirectly, from the serious nature of the lesions of the urinary organs to which it may give rise, schistosomum is an occasional cause of death.

The most characteristic symptom of its presence in the wall of the bladder is the passage of blood at the end of micturition, with or without a sense of urinary irritation. The quantity of blood passed and the degree of irritation are increased by exercise, by dietetic indiscretions, and by all such causes as are calculated to induce or aggravate cystitis. As a rule,

it is only the last few drops of urine that contain blood; sometimes, however, the hæmorrhage is more extensive, and then the entire bulk of the urine may be blood-tinged. Occasionally, clots even are passed.

If in a case of moderate infection the urine be passed into a glass and held up to the light, minute flocculi, or coiled-up mucoid-looking threads, will be seen floating about in the fluid. If it be allowed to stand, the flocculi, and perhaps minute clots, will subside to the bottom of the vessel; these, on being taken up with a pipette and placed under the microscope, will be found to contain, besides blood corpuscles and the usual catarrhal products, large numbers of the characteristic spined ova.

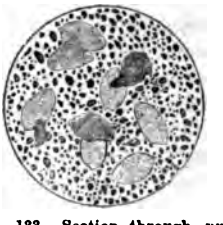


Fig. 133.—Section through nucleus of urinary calculus containing ova of Schistosomum hæmatobium.

In doubtful cases, where ova are few, the best way to find them is to get the patient to empty the bladder and to catch in a watch-glass the last few drops of urine which can be forced out by straining; these invariably contain ova. A low power of the microscope suffices, and is best for diagnosis.

Endemic hæmaturia lasts for months or years. Recovery is rarely complete. In ordinary cases, provided no reinfection take place, the hæmaturia tends to decrease, although ova may continue for years to be found in the last few drops of urine passed. In severe cases, sooner or later, signs of cystitis supervene and give rise to a great deal of suffering. Not infrequently the ova become the nuclei for stone, and symptoms of urinary calculus are superadded. (Fig. 133.) Sometimes the pathological changes induced by the presence of the parasite in the bladder lead to the development of new growth, in which event the symptoms become more urgent and the hæmaturia perhaps excessive. Hypertrophy, contraction, and even dilatation of the bladder, are not unusual.

Besides the bladder symptoms there may be signs of prostatic disease, or of disease of the vesiculæ seminales causing spermatorrhœa. In the latter case, ova may be detected in the semen. In other instances the ureters and kidneys become involved, and grave disease of these organs ultimately ensues. In consequence of the suffering which these aggravated forms of infection produce, the patients become anæmic, wasted, debilitated, and a ready prey to intercurrent disease.

Milton has pointed out the extreme frequency of urinary fistula in Egypt, the result of schistosomum disease of the urethra. These fistulæ may occur anywhere in the neighbourhood of the genitals, but are especially common in the perineum and posterior surface of the scrotum, and originate from schistosomum disease of the pubic surface or roof of the urethra just in front of the bulb, the eggs of the parasite being deposited in the mucous or submucous tissue. Stricture of the urethra is by no means uncommon from a similar cause, especially in the case of fistulæ connected with the floor of the urethra.

Vaginitis and cervicitis have been known to be produced by this parasite. On the vulva papillomatous masses containing schistosomum ova are, according to Madden, very common.

Besides the lesions of the genito-urinary organs, rectal symptoms have been described and the characteristic ova of *S. hæmatobium* have been found in the rectum. Frequently, however, another species (*S. mansoni*), which invariably extrudes its eggs through the intestine, has been confounded with the old classic species. The intestinal lesions give rise to dysenteric-like symptoms. Very often mucus and blood are passed without any fæcal matter, and the continuous straining may be distressing, especially when large polypoid masses protrude from the anus. Recently I saw a case in which extensive condyloma-like growths around the anus, in the perineum and groin, and full of ova, were a remarkable feature.

Pathological anatomy. — The character of the changes brought about by schistosomum varies

very much according to the degree and the duration of the infection. In almost every case of the Egyptian type of the disease the walls of the urinary bladder are early affected. All that may be apparent to the naked eye at this stage is a certain amount of injection of the small vessels of the mucosa vesicæ, and, according to Sonsino, certain exceedingly minute vesicular or papular elevations of the surface of this membrane. When these minute elevations are examined microscopically they are found to contain ova. Ova are also to be found in the dilated minute blood-vessels. Later, especially in the trigone of the bladder, there are found rounded patches of inflammatory thickening which project somewhat, are granular on the surface, and dense in consistence; on section they creak under the knife as if they contained gritty particles. It is evident that these elevated, thickened patches are the result of an inflammatory process provoked by the clusters of ova which the microscope reveals scattered throughout their entire extent. The ova are principally deposited in the submucosa, less extensively in the mucous membrane itself, still less abundantly in the muscular walls of the organ or in its subserous connective tissue. They tend to occur in groups, each of which is invested with a sort of connective-tissue capsule; or they may be lying in small blood-vessels which they occlude. Some ova are seen to have undergone calcification; others are still fresh, either segmenting, or already containing a miracidium. On the surface of the rounded patches already mentioned phosphatic deposits, also containing ova, are not uncommon; sometimes the patches present minute sloughs. Besides these indurated patches, various forms of polypoid excrescence—sometimes ulcerated—may protrude from the mucous surface into the cavity of the bladder. These various hyperplasiæ frequently contain the adult parasite as well as ova.

In addition to what may be designated the specific changes in the mucosa, the muscular coats of the bladder are generally hypertrophied. In consequence of this, as well as of the ingrowth of villosities

and different forms of new growth, the capacity of the organ may be much diminished. Its mucous surface is generally coated with a sanguineous mucus containing myriads of ova. Gravel, or small stones —generally phosphatic—are sometimes found either embedded in lacunæ in the hypertrophied and roughened bladder wall, or free in the cavity. Not infrequently a similar hyperplasia occurs in the ureters, and particularly towards their lower ends. In rare instances the pelvis of the kidney itself is affected. Obliteration of the ureter, both from small stones and from thickening of the mucous membrane, has sometimes been met with; this leads to dilatation of the pelvis and atrophy of the parenchyma of the kidney. It is easy to understand how, in time, these changes in the bladder and ureters may give rise to hydronephrosis, pyelitis, abscess of the kidney, and similar secondary affections.

Hyperplasia from schistosomum infection may also occur in the vesiculæ seminales, in the walls of the vagina, and in the cervix of the uterus, leading to corresponding bloody, ova-containing discharges.

When the intestinal tract is involved numerous polypoid adenomatous growths are found, especially in the rectum; these usually slough off, leaving ulcerations with ragged edges. The coats of the gut become thickened and indurated owing to extensive fibrous tissue formation between the layers of the peritoneal attachments.

It may be mentioned that schistosome ova in small numbers have been found in the liver, in gall-stones, in the lungs, in the heart, and in the kidneys. We have no knowledge of any definite pathological change entailed by their presence there.

Tumours of schistosomum origin have sometimes been found in connection with the peritoneum and ligaments of the uterus.

Diagnosis.—The diagnosis of this disease is not difficult; the presence of ova in the urine is decisive. In countries like Egypt, where the disease must often concur with chyluria, with stone, with vesical tumour, with gonorrhœal cystitis, and with pyelitis, as well as

with prostatic disease, care must be exercised in each particular case to separate the special factors to which the various symptoms are attributable. Thus in chyluria concurring with schistosomum disease there will be chyle in the urine in addition to blood. In such a combination the clot which forms will be large, will contain oil granules and globules and, very probably, microfilariæ, in addition to schistosomum ova; moreover, the microfilariæ will generally be detectable in the finger blood if looked for at night. Stone in the bladder, when suspected, has to be searched for with the sound. In gonorrhœal cystitis the history of gonorrhœa will be forthcoming. In prostatic disease enlargement of this organ may be made out. Difficulty may sometimes arise when ova are few in number, or when they have ceased altogether to come away in consequence of the death of the parent worms. The mischief wrought by the parasite remains, although the ova—the most certain evidence of the parasite's previous presence—may be discharged no longer. But, even if ova are very few, they may still be found in the last drop or two of urine passed. If they are no longer to be found in the urine, sometimes, by scratching the surface of the bladder with a sound and examining the shreds of mucus so obtained, a few, calcified it may be, but presenting the characteristic spine, may be seen with the microscope.

In rectal disease, if schistosomum be suspected, the mucus and fæces, or failing these one of the adenomatous growths, after removal by finger or forceps, should be examined for ova.

Prognosis.—An important element to be considered in venturing on a prognosis is the long life of the parasite. Sonsino mentions a case in which living ova were still being passed nine years after their first appearance, and after all chance of reinfection had ceased. Another important element in prognosis is the degree of infection; the greater the number of worms the more severe and the more extensive the disease they produce. As with filarial infection, the greater the number of cases in a district the greater

the proportionate probability of severe infections being met with. The prognosis is practically that of a chronic cystitis depending on an irremediable, but not in itself fatal, cause. Much suffering may often be produced, and, as a consequence, anæmia and debility. Possibly calculus may be formed; possibly grave renal disease may ensue; possibly villous or epitheliomatous growths in the bladder. In the milder degrees of infection, which fortunately are the commonest, the patient seems to be in no way inconvenienced by the parasite, and generally escapes all serious consequences. In any case, mild or severe, there may be attacks of hæmaturia from time to time; as a rule, the quantity of blood lost is insignificant.

Treatment.—Our knowledge of the situations occupied by the parasite indicates the futility of attempting a radical cure by means of poisonous substances, whether introduced by the bladder, by the rectum, or by the stomach. As yet we know of no direct or other means by which the schistosomes can be destroyed. Only harm can result from attempts at a radical cure of endemic hæmaturia on such lines. Our efforts must, therefore, be confined to palliating the effects of the presence of the parasite. Practically, the treatment resolves itself into that of chronic cystitis. The diet should be bland but nutritious; stimulants and spices are to be avoided. Excess of all kinds, violent muscular efforts, cold and other causes of catarrh, must also be guarded against. During exacerbations of hæmaturia, or of cystitis, rest should be enjoined and diluents freely partaken of. Milton has obtained good results from gramme doses of extract of male fern three times a day in schistosomum hæmaturia. A recent writer has advocated the use of methylene blue (3 gr. three times a day) in similar circumstances. Adrenalin has some influence in controlling hæmorrhage. Salvarsan has been tried, but was found to be of no use. Pain may demand anodynes. Excessive catarrh of the bladder suggests washing out with weak boric-acid lotion, and the internal administration of urotropine, uva ursi, buchu, perhaps small doses of cubebs, copaiba, or

sandal-wood oil, salol, benzoic acid, and so forth. Stone, and troublesome new growths, are to be removed by operation. Where distress was extreme, Mackie and others have had good results from perineal cystotomy and drainage. Adenomatous growths in the rectum, where accessible, should be removed. In severe rectal disease, milder measures failing, excision of the affected part of the gut may be necessary. Perineal fistula must be dealt with on ordinary surgical principles. Hyperplasia in the vagina and cervix is best treated by scraping.

Prevention.—Since analogy justifies the belief that the larva of schistosomum, on obtaining access to fresh water, enters a fresh-water animal and by it obtains access to another human host, it is evident that if the larva be kept from getting into the water, or, if drinking-water be boiled or filtered, the spread of the disease from man to man would be effectually prevented.

In the endemic districts, children, in particular, should be carefully and repeatedly warned against drinking or bathing in water of ponds and canals. Provided reinfection be avoided by the exercise of prudence in the matter of water, there is no necessity for sending the patient with schistosomum disease away from the country in which the parasite was acquired.

Every care should be exercised to prevent the diffusion of the disease, by prohibiting the evacuation of excreta into water where the miracidia might find the opportunity of development and transmission. This prohibition should not be restricted to patients, but extended to all, because, as special inquiries have shown, a large proportion of the infected do not suffer from any troublesome symptom, and are often unaware of the infection.

SCHISTOSOMUM MANSONI, Sambon, 1907

The occurrence of a schistosomum producing lateral-spined ova (Plate XIII., Fig. 2) was noticed by Bilharz in 1851, but, believing the ova to represent peculiar capsules formed by the larvæ after hatch-

ing, he confounded it with *S. hæmatobium*. After Bilharz several observers encountered female worms with lateral-spined ova in utero, and the idea of a distinct species suggested itself to Sonsino and others, but this idea was at once discarded for other hypotheses. The lateral-spined ova being found only* in the fæces of Egyptian patients suffering from hæmaturia, the majority of physicians held that the peculiar position of the spine was due to distortion of the egg-shell in passing through the muscular coat of the rectum, forgetting that oviposition takes place in the submucous layer, and that lateral-spined ova are found in the uterus of the parent worm. Sonsino suggested that the two kinds of eggs might represent respectively male and female embryos. Looss surmised that the lateral-spined ova might be the product of unfertilized females; but if, as Looss suggests, the lateral-spined are merely unfertilized ova, how then is the species propagated in America, where the rectal lateral-spined ova are the only ones found?

In 1903, in examining a patient who had long resided in Antigua and other West Indian islands and who had never visited Africa, I found in his fæces numerous schistosomum eggs all bearing a lateral spine. Repeated examination of the urine proved negative, and the patient stated that he had never at any time suffered from hæmaturia. This case, together with the absence of endemic hæmaturia in the West Indies, led me to think that probably the lateral-spined ova indicated a distinct species of schistosomum, and I suggested this in a previous edition of this manual and elsewhere. Since then a considerable amount of information has accumulated in favour of my conjecture. A new species of schistosomum (*S. japonicum*) with what are practically spineless ova, and affecting the intestine only, has been discovered in Japan, and careful examinations for helminths in the Congo Free State (Broden) and in Porto Rico (Gunn and others) have shown the

* Lately, Bandi states that he found in Tunisia 25 cases of vesical bilharziosis with lateral- and terminal-spined ova in the urine. His experience is certainly very exceptional.

absence of urinary schistosomum disease and the frequency in these regions of a rectal schistosomum infection in which the ova of the parasite bear invariably a lateral spine. Finally, Sambon (*Proceedings of the Zoological Society*, March 9th, 1907), having had the opportunity of comparing specimens of the type characterized by lateral-spined ova with *S. hæmatobium* and other schistosomidæ, and taking into consideration its peculiar geographical distribution and distinct pathogeny, proposed that it should be ranked as a distinct species, and paid me the compliment of naming it *S. mansoni* in recognition of my suggestion. Since that time many cases of lateral-spined rectal bilharziosis have been reported from America by Flu (Surinam) and others. So far as I am aware, not a single case of terminal-spined bilharziosis of indigenous origin has been observed on that continent.

The available material being very badly preserved, Sambon was unable to furnish the exact dimensions and the anatomical details of the new species, which closely resembles *S. hæmatobium* in general appearance and structure.* His determination is based chiefly on the egg characters. After stating that other species of animals, as for example an ostrich (Rhea), have been established solely on the characters of their eggs, Sambon calls attention to the fact that all the schistosomidæ of man and cattle are very much alike in general morphology, the only striking and characteristic difference being that of their ova, which differ markedly in each species. In *S. hæmatobium* the eggs are more or less ovoid and provided with a short straight terminal spine; in *S. bovis* they are spindle-shaped and provided with a short terminal heart-shaped spine; in *S. japonicum* they are ovoid and have no well-defined spine; and in *S. mansoni* they are oval and provided with a large thick lateral spine.

In careful comparative examination Flu has shown that there are several structural differences

* In both species the males present a tuberculated outer surface, but the number and shape of the prominences seem to differ somewhat.

between the adult *S. hæmatobium* and *S. mansoni*. He finds that whereas in the male *S. hæmatobium* the anterior border of the lateral folds forms almost a right angle with the long axis of the body, in *S. mansoni* the folds are gradually sloped off. In the female *S. mansoni* the ovaries run a tortuous course unlike those in other schistosomes, the oötype is asymmetrical, and the oviduct opens laterally on the ventral side where the shell gland is situated. In sixty females he found only lateral-spined ova.*

Apparently *S. mansoni*, like *Necator americanus*, is a West African species which has been introduced into the western hemisphere by the African negro.

S. mansoni inhabits chiefly the mesenteric veins, and its ova deposited within the submucous layer of the rectum give rise to dysenteric-like symptoms, mucus with blood being passed from time to time, the ova-laden stools becoming frequent and their passage perhaps being attended with tenesmus. In such cases small, sometimes large, branching, soft growths are to be felt inside the sphincter ani. They resemble polypoid growths, and are apt to be mistaken for piles. They may extend as high up the bowel as the sigmoid flexure. On tearing up one of these growths the ova can be seen in the débris.

The eggs of *S. mansoni* have been found also in the liver, giving rise to a peculiar form of cirrhosis.

SCHISTOSOMUM JAPONICUM (Katsurada, 1904) (Plate XIV.)

Synonym.—*Schistosomum cattoi*, Blanchard.

History.—For some years Japanese physicians had observed in the provinces of Yamanashi and Hiroshima in Central Japan, and at Saga in the North Island, an endemic disease characterized by enlargement of the liver and spleen, cachexia and

* Holcomb mentions five autochthonous cases of intestinal schistosomum infection in the island of Vieques. The ova of the parasite were invariably lateral-spined. He states that 167 similar cases have been reported in Porto Rico; the eggs being found solely in the fæces, never in the urine.

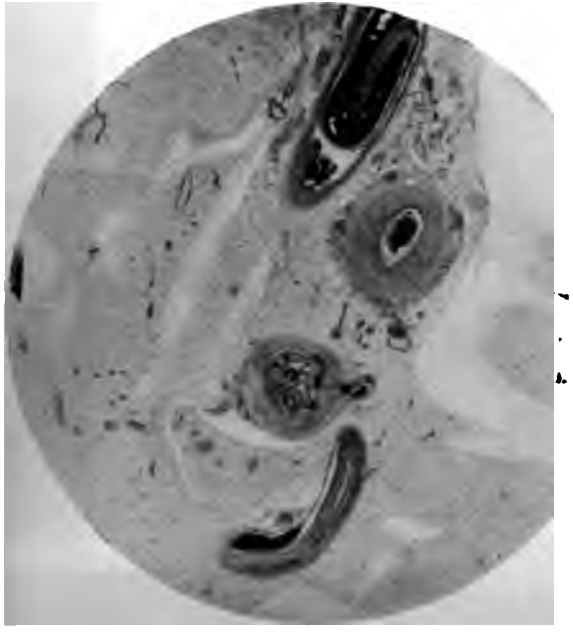


Fig. 1.—Schistosomum japonicum in vessels of mesentery. (*Microphoto: Dr. Henderson.*)

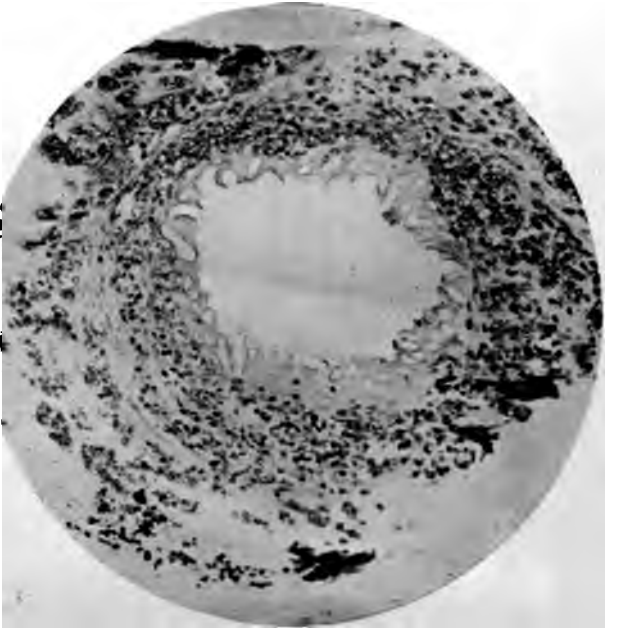


Fig. 2.—Eggs of Schistosomum japonicum embedded in walls of appendix vermiformis. (*Microphoto: Dr. Kerr.*)

PLATE XIV.

ascites. The patients suffered from diarrhœa, their motions containing mucus tinged with blood. Occasionally they had fever. They became anæmic, and many of them died from exhaustion. At the autopsy the liver and other organs were found to contain the ova of some unknown helminth.* In April, 1904, Katsurada discovered that the eggs found in the stools of these patients contained a ciliated embryo not unlike the miracidium of *Schistosomum hæmatobium*. Disappointed of an autopsy, he examined dogs and cats in the endemic area, and had the good fortune to find at once in the portal system of two cats from the province of Yamanashi numerous schistosomidæ containing eggs exactly similar to those previously found in man. He published this information on August 13th, 1904, and named the new trematode *S. japonicum*. Almost simultaneously, and independently, Fujinami observed cases of the disease in the village of Katayama, in the province of Bingo, and found in his first fatal case the characteristic ova in various organs. In a second necropsy, besides the ova in the liver, intestinal wall, and mesenteric glands, he found in a branch of the portal vein a parasite which he regarded as *S. hæmatobium*. In November, 1904, Catto discovered the same parasite in sections of the mesocolon from a Chinaman of the province of Fukien who died of cholera at St. John's Island Quarantine Station, Singapore.

The parasite (Fig. 134).—*Schistosomum japonicum* closely resembles in general structure *S. hæmatobium*. As in the latter, the suckers are placed close together at the anterior extremity of the body, the acetabulum or posterior sucker being distinctly pedunculated and funnel-shaped. The suckers in both sexes and the ventral surface of the body in the male are provided with minute spines. The distinctive characters of the new trematode are its smaller dimensions (male, 9 to 12 mm. in length by 0·5 mm. in breadth; female, 12 mm. in length by 0·4 mm. in breadth), and the larger size of the acetabulum as compared to the oral sucker. In the

* As far back as 1888, Majima, in Tokio, found peculiar ova in the liver of a case of cirrhosis. These he described as the ova of an unknown parasite. In 1890, in a similar case, Yamagiwa found ova which he ascribed to the lung trematode.

male the integument is smooth and non-tuberculated, and the posterior part of the body in the male is relatively wider, the sides overlapping one another far more extensively than in *S. hæmatobium*. Finally, the ova (70 to 75 μ in length, 45 to 55 μ in breadth) are smooth and possess no spine; but they possess, as Leiper has pointed out, what may pass as a rudimentary lateral spine in the form of a very minute and easily overlooked papilla—like an excrescence, in a cup-like depression in the shell. (Fig. 135.) A comparative study of the anatomy of the two schistosomidæ will probably show other morphological differences. Catto mentions a larger vas deferens and lobular testicles in the male, and a different arrangement of the yolk cells in the female. Looss notices a greater development of the muscular system in the male *S. japonicum*, which he thinks may take the place of the absent cuticular eminences.

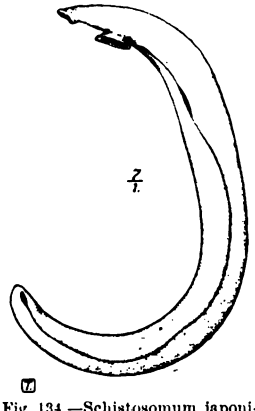


Fig. 134.—Schistosomum japonicum (male).

Catto found the adult worms in the smaller mesenteric blood-vessels, but he was unable to determine whether they occupy the arteries or the veins. He believes they occur in both. The smooth, non-tuberculated skin of *S. japonicum* seems to suggest a different anatomical habitat from that of *S. hæmatobium*, the integument of which is beset with numerous spine-bearing protuberances. *S. hæmatobium*, inhabiting the venous system, has a rough integument, it may be to enable it to adhere to the inner coat of the venules, and to stem the blood-stream during oviposition. *S. japonicum*, inhabiting the arteries, requires no integumental protuberances, the direction of the arterial current maintaining it in its proper position.

In Catto's case the ova were found chiefly in the mucous and submucous coats of the intestinal tract from cæcum to anus, more especially in the rectum and appendix. They were also found in the liver, in the gall-bladder, in the pancreas, in the mesenteric glands, and in the fibrous coat of the larger mesenteric vessels. In the liver they were very plentiful, lying singly or in clusters embedded in the hypertrophied connective tissue. The female schistosomum probably has a special means of extruding her eggs through the walls of the blood-vessels; the further distribution of the eggs being affected by the lymph-stream. Where the ova accumulate they provoke a small-cell infiltration, which gives place later to fibrous tissue.

The ova contain a ciliated miracidium, which may develop in the fæces even before they are evacuated. The parasite, therefore, needs water during its miracidium stage, and, possibly, some fresh-water mollusc or crustacean for further development. Katsurada has succeeded in communicating the parasite to cats by immersing their legs in the water of certain ponds and streams reputed to convey this disease.

Geographical distribution.—The distribution of *S. japonicum* is probably a wide one. So far it has been found principally in Chinese and Japanese. It is far from uncommon in the Philippines, or in the Yangtze valley, where a notable proportion of the boatmen and raftsmen and farmers have been found infected. Europeans also have acquired the disease in the latter district, mostly sportsmen addicted to snipe-shooting in the rice fields.

Fig. 135.—Egg of Schistosomum japonicum, showing characteristic lateral knob. (*After Leiper.*)

Morbid anatomy.—Catto's patient during life presented enlargement of the liver and spleen. At the autopsy the appearance of the peritoneum suggested repeated attacks of peritonitis. The appendices epiploicæ were thickened, and in some places matted together. The recto-vesical pouch was almost obliterated. The mesenteric and prevertebral glands were enlarged, the largest group forming a cluster near the duodenum. The liver was considerably hypertrophied, its surface nodular, its consistence greatly increased. The coats of the gall-bladder were thickened, and a layer of fat almost completely encased this organ, which was distended with clear mucoid material containing several minute black gall-stones. The spleen was enlarged and pigmented. The colon was much thickened throughout. Its mucous membrane was swollen, hyperæmic, and friable; it presented numerous small circular superficial erosions and patches of necrosis. The outer coats were very tough, almost cartilaginous. The walls of the rectum were three-quarters of an inch thick and adhered to the bladder. It nearly filled the true pelvis.

The sigmoid flexure also was uniformly thickened. In tracing the bowel upwards the thickening became less marked and more patchy. The liver and bowel cut gritty on section. The bladder was thickened where adhesions had formed with the rectum, but elsewhere it was healthy, and nowhere was the vesical mucosa diseased. Sections of the liver, mesenteric glands, and bowel were found to contain the ova of *S. japonicum.*

In a case from Katayama, described by Tsunoda and Shimamura, the necropsy revealed, besides the ordinary lesions in the liver, intestine, and pancreas, thickening, with hæmorrhagic infiltration of both the dura and pia mater. In the brain itself a number of wedge-shaped sclerosed areas of greyish colour, and surrounded by some ecchymosis, were found. In the lenticular nucleus, optic thalamus, and internal capsule of the left side there was an area of softening the size of a walnut. On histological examination these areas were found to contain ova embedded in neuroglia and surrounded by softened and degenerated brain tissue. Similar ova were found in the membranes, and a few in the right hemisphere and in the choroid plexuses of the lateral ventricles. In connection with these lesions the patient during life suffered from disorder of speech and tremor in both upper and lower extremities, with headache and mental disturbance, later from vertigo and Jacksonian fits (two or three daily), and finally from right hemiplegia.

Katsurada has drawn attention to the fact that *S. japonicum* does not affect the bladder. The two cases described in Chinamen confirm this experience. These are, therefore, important pathological and clinical features which, in addition to the zoological characters of the parasites, show that *S. japonicum* is specifically distinct from *S. hæmatobium* and *S. mansoni.*

Symptoms.—The disease produced by *S. japonicum*, sometimes called "Katayama disease," is a grave one, and when pronounced proves fatal sooner or later. The gravity of any given case will depend, amongst

other things, on the degree of infection and the circumstances of the patient. A history of fever accompanied by an urticarial eruption is generally given — sometimes there are associated with this symptoms of pulmonary congestion. After an interval of several weeks or months, intestinal troubles, in the form of dysenteric discharges, dyspepsia, together with great enlargement of liver and spleen, set in; these persisting, a characteristic cachexia—intense anæmia, ascites, wasting, and progressive debility—supervenes; ultimately, if the patient does not succumb to some superadded disease, terminating—it may not be for many years—in death.

Diagnosis.—All cases of urticarial fever from the endemic districts should be watched for many months, especially if eosinophilia persists after the subsidence of the primary attack, and the stools examined for ova of *S. japonicum*. All cases of chronic intestinal disturbance, especially if associated with enlargement of liver and spleen, from these districts should be regarded as possibly cases of schistosomiasis and have the blood and stools examined. If the ova are discovered the diagnosis is established.

Prevention.—Water reported to cause the disease should be boiled or avoided for drinking or bathing purposes. Sportsmen, if they must wade in such waters, should wear long boots or puttees.

Treatment.—No specific remedy is known. Filix mas may be tried, otherwise the treatment is entirely symptomatic.

CHAPTER XLII

II. PARASITES OF THE CONNECTIVE TISSUE

DRACUNCULUS MEDINENSIS, Velsch, 1674

Synonyms.—*Vena medinensis; Dracunculus persarum; Gordius medinensis; Filaria dracunculus; F. medinensis; Guinea-worm.*

Geographical distribution.—This important parasite is found in certain parts of India—the Deccan, Scinde, etc.—in Persia, Turkestan, Arabia, tropical Africa—particularly on the West Coast, and in a very limited part of Brazil (Feira de Santa Anna). Formerly it was supposed to be endemic in Curaçoa, Demerara, and Surinam; apparently it has now disappeared from these places. Dracunculus is not equally diffused throughout this extensive area; it tends to special prevalence in limited districts, in some of which it is excessively common. In parts of the Deccan, for example, at certain seasons of the year nearly half the population is affected; and in places on the West Coast of Africa nearly every negro has one or more specimens about him. Although guinea-worm is sometimes seen in Europe, this is only in natives of, or in recent visitors from, the endemic areas. Though frequently introduced in this way, it has not become established either in Europe or in North America. We have no account of the parasite as endemic in any part of Asia east of Hindustan, in the Eastern Archipelago, in Australia, or in the Pacific islands.

Dracunculus medinensis has been reported for horses, oxen, dogs, wild cats, jackals, leopards, and other animals. Possibly some of the parasites in the lower animals described as guinea-worm may belong to quite a different species.

The parasite (Figs. 136–8).—The female is reputed to attain in some instances enormous dimensions; it is probable, however, that worms of 5 or 6 ft. in length owe their size to errors of observation, two worms, or their fragments, having been regarded as one. According to Ewart, in forty carefully measured specimens the smallest was about 32·5 cm., the largest 1 m. 20 cm. in length; 90 cm. is probably an average length. The diameter of the worm is about 1·5 to

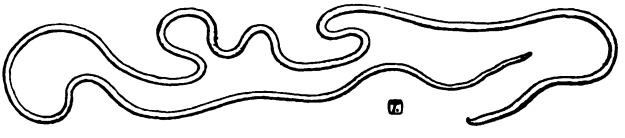


Fig. 136.—Dracunculus medinensis (reduced).

1·7 mm. The body is cylindrical, milky-white, smooth, and without markings. The tip of the tail comes to a point and is abruptly bent, thus forming a sort of blunted hook, perhaps functioning as a "holdfast." The head end is rounded off, terminating in what is known as the cephalic shield. The mouth is triangular, very small, and surrounded by six papillæ—two large and four small. The alimentary canal is relatively small, being compressed and thrust to one side by the uterus; in the mature worm it is probably cæcal, for it has not been traced to an anus. Nearly the entire worm is occupied by the uterus, which is packed from end to end with coiled-up embryos. The vagina also may be lacking. According to Looss, the uterine tubes (he states, contrary to Leuckart, that there are two) open into the posterior part of the œsophagus by a common duct, the œsophagus prolapsing through the mouth at the time of parturition and being subsequently withdrawn. Leiper, however, has shown that the worm discharges its young by a prolapse of the uterus as described by me, and that the extrusion does not occur through the mouth, as suggested by Looss and myself, but by an opening just outside the circumoral ring of papillæ, possibly the vagina.

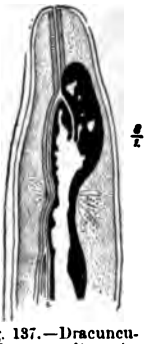


Fig. 137.—Dracunculus medinensis. (*After Leuckart.*)

Nothing definite is known of the male worm. According to Polak, the Persians have long known the male to be a smaller worm, 7–10 cm. long. They stated that at times as many as twenty of these small worms might be found coiled round a female specimen. Charles described a shorter (4 cm.) worm, regarding it as the male, which he found

twice attached to the larger female worm within the sub-peritoneal connective tissue. Charles's description does not exclude the possibility that what he describes as the male worm *in coïtu* was really a prolapse of the uterus through the ruptured integument. Daniels, at the post-mortem of a monkey experimentally infected by Leiper six months previously, found three immature females (30 cm. long) and two remarkably small males (22 mm.), which were obtained, one from the psoas muscle and the other from the connective tissue behind the œsophagus.

Habits.—The habitat of the female guinea-worm is the connective tissue of the limbs and trunk. When mature, and prompted by instinct, she proceeds to bore her way through this tissue, travelling downwards. In 85 per cent. of cases she presents in some part of the lower extremities. Occasionally she presents in the scrotum; rarely in the arms (Fig. 139); exceptionally in other parts of the body, or even in the head. In a proportion of cases the appearance of the worm at the surface of the body is preceded by slight fever and urticaria, as described by Sutherland in 1897 and by Bartet independently in 1898. Arrived at her destination she pierces the derma. Probably in consequence of some irritating secretion, a small blister now forms and elevates the epidermis over the site of the hole in the derma. By and by the blister ruptures, disclosing a small superficial erosion $\frac{1}{2}$–$\frac{3}{4}$ in. in diameter. At the centre of the erosion, which some-

Fig. 138.—Transverse section of D. medinensis. (*Leuckart.*)

times quickly heals spontaneously, a minute hole, large enough to admit an ordinary probe, can be seen. Sometimes, when the blister ruptures, the head of the worm is seen protruding from this hole; as a rule, however, at first the worm does not show. If now we douche the neighbourhood of the ulcer with a stream of cold water

[Photo: P. H. Bahr.

Fig. 139.—Female guinea-worm lying under the skin of the forearm.

expressed from a sponge and, as the water falls, watch the little hole in the centre of the erosion, we shall see in a few seconds a droplet of fluid—at first clear, later milky—well up through the hole and flow over the surface. Sometimes, instead of this fluid, a small, beautifully pellucid tube, about 1 mm. in diameter, doubtless the uterus of the worm prolapsed through her head parts, is projected through the hole in response to the stimulus of the cold

water. When this tube has been extruded an inch or thereabouts, it suddenly fills with an opaque whitish material, ruptures and collapses, the fluid spreading over the surface of the erosion. If a little of the fluid, either that which has welled up through

Fig. 140.—Embryos of D. medinensis. (*From a microphotograph by Mr. H. B. Bristow.*)

the hole, or that which has escaped from the ruptured tube, is placed under the microscope, it is seen to contain myriads of dracunculus larvæ lying coiled up, almost motionless, with their tails projecting in a very characteristic manner (Fig. 140). If now a drop of water be instilled below the cover-glass the larvæ

may be observed to unroll themselves and, in a very short time, to swim about, *more suo*, with great activity. Manifestly these larvæ come from a guinea-worm lying in the tissues and communicating with the surface through the little hole in the derma. If the douching be repeated after an hour or longer a further supply of larvæ can be obtained; and this can be continued from time to time until the worm has emptied herself. Apparently the cold applied to the skin of the host stimulates the worm to contract and thereby force out her uterus, inch by inch, until it is completely expelled. When the protruded portion of uterus ruptures, under the pressure of the *vis a tergo*, it shrivels up, dries, and thus effectually seals up the end of that part of the organ which is still inside the worm, thereby preventing what might be inopportune and too prodigal discharge of larvæ.

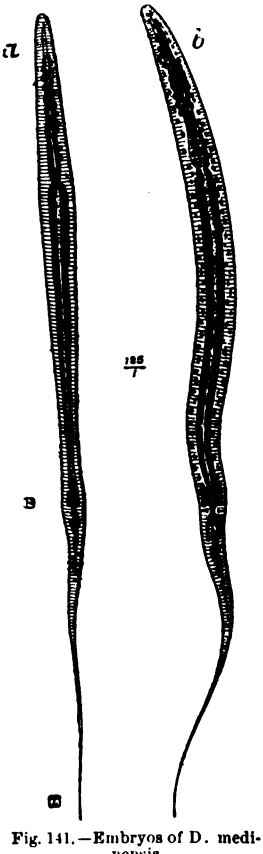


Fig. 141.—Embryos of D. medinensis.
a, Side view; *b* (*after Looss*), front view.

The larva (Fig. 141).—The larvæ are not cylindrical; they are distinctly flattened. In swimming they move by a sort of side-to-side lashing of the tail, and tadpole-like motion of the body. The movements are intermittent; sudden, short swims alternating with brief pauses. When progressing, the greater transverse axis of the body is perpendicular to the plane travelled over; but when, from time to time, the little worms pause, they gradually roll over on to their flat surfaces. As soon as they come to rest on the flat they

suddenly recover themselves with a jerk, and turn quickly on to their edges and begin swimming about again. This series of movements is constantly repeated.

The larva of *D. medinensis* measures about 15 to 25 mm. in length by 0·50 to 0·75 mm. at its greatest breadth. The head is somewhat tapered and then abruptly rounded off. The tail is long, slender, but not quite sharply pointed. The alimentary canal can be readily detected. Towards the root of the tail two peculiar gland-like organs, placed opposite to each other,

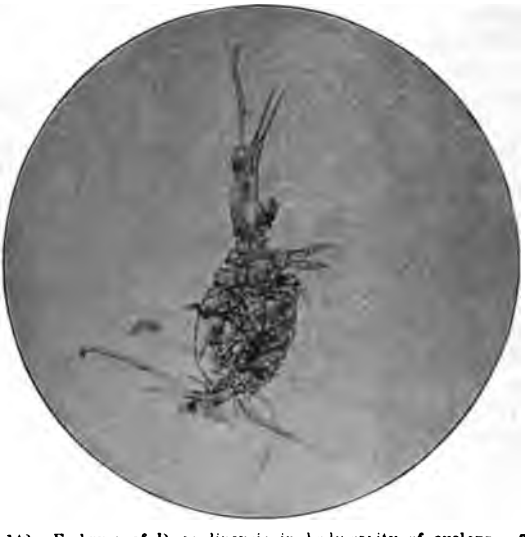


Fig. 142.—Embryos of D. medinensis in body cavity of cyclops. The cyclops has been slightly compressed so as to force out some of the worms, which can be seen escaping from ruptures at the head and tail. (*From a photograph by Mr. Andrew Pringle.*)

can be made out. The cuticle is very distinctly transversely striated.

In clean water the larva remains alive for six days; in muddy water, or in moist earth, it will live from two to three weeks. If slowly desiccated it does not die; it may be resuscitated by placing it again in a little water.

Intermediary host.—If, by way of experiment, we place some dracunculus larvæ along with *Cyclops quadricornis* in a watch-glass we shall find that, after a few hours, the larvæ have transferred themselves to the interior of the body cavity of the cyclops, where they can be seen moving about, coiling and uncoiling themselves, with considerable activity (Fig. 142).

As many as fifteen or twenty young guinea-worms may be counted in each of the little crustaceans, which, unless the infection is excessive, seem in no way inconvenienced. After a time the embryos so transferred undergo a metamorphosis. They cast their skins two or three times, get rid of their long swimming tails, acquire a cylindrical shape and, ultimately, along with increased size, develop a tripartite arrangement of the extreme posterior end, which recalls a similar arrangement of the tail of *F. bancrofti* and of *F. recondita* towards the termination of the stay of the former nematode in the mosquito, and of the latter in the dog-flea (Grassi).

Mode of infection. — The metamorphosis of *D. medinensis* in cyclops was discovered by Fedschenko in Turkestan. His observations I have been able to confirm in England; but, owing to the colder climate of the latter country, in English cyclops the metamorphosis takes somewhat longer to complete—eight or nine weeks, instead of five weeks as in Turkestan. Fedschenko supposed that the cyclops containing the larvæ of the guinea-worm, on being swallowed by man in drinking-water, was digested; and that the parasite, being then set free, worked its way into the tissues of its new and definitive host; but all the experiments he made to bring about infection by means of ingestion of cyclops containing dracunculus larvæ gave a negative result. These failures led to the belief that the larvæ might have to undergo further changes before it was fitted for life in man. Considering the peculiar geographical limitations of this helminthiasis, and the very general distribution of cyclops, such an arrangement seemed likely enough.*

Recently, Leiper has shown that when an infected cyclops is transferred to a 0·2 per cent. solution of hydrochloric acid it is immediately killed, but the larvæ, so far from being destroyed, are aroused to great activity, and eventually escape into the fluid, in which they swim freely. From this he conjectured that under natural conditions man becomes infected through the ingestion of infected cyclops, the gastric juice acting on cyclops and larva in the same way as the hydrochloric acid in his experiment. In

* One German observer has stated that he succeeded in communicating guinea-worm to a monkey by applying the embryos to the skin of the animal.

order to prove this he fed a monkey on bananas concealing cyclops which had been infected for five weeks, and which contained fully developed larvæ. Six months later, when the monkey died, five worms were found in its connective tissues, all possessing the anatomical characteristics of *D. medinensis*.

The evidence is now fairly complete that the life span of the female dracunculus extends to about one year, conforming probably to the habits of certain species of cyclops which, under natural conditions, serve as its intermediary host. It is not to be supposed that every species of cyclops is an effective intermediary; for, were this the case, guinea-worm would have a much wider geographical range.

Biological peculiarities explained.—The little we now know of the life history of the guinea-worm explains many things that were formerly mysterious. We now understand why the parasite, on attaining maturity, makes for the legs and feet; these are the parts of the human body most likely, in tropical countries, to come in contact with puddles of water, the medium in which cyclops—the intermediary host—lives. We can understand, also, why it is that the contact of water with the skin of the host causes the guinea-worm to expel her young; and we can understand the rationale of the douching so much practised by the natives of certain of the endemic districts in their attempts at extraction. The water-carriers in India are said to be very subject to guinea-worm, which, in their case, is prone to appear on the back—that is, the part of the body against which the water-skin lies when being carried. On this fact has been based an hypothesis that the young guinea-worm enters by the skin. I would interpret the fact, if fact it be, by suggesting that the mature guinea-worm, conformably to her instinct, seeks out that part of the body most in contact with water, which, in the case of the Indian water-carrier, is his back.

Premature death of parasite.—Occasionally the guinea-worm fails to pierce the integument of her host; sometimes she dies before arriving at maturity. In either case she may give rise to abscess; or she

may become cretified, and in this condition may be felt, years afterwards, as a hard convoluted cord under the skin of the leg, or be discovered only on dissection.

Treatment.—Formerly it was the custom, so soon as a guinea-worm showed herself, to attach the protruding part to a piece of wood and endeavour to wind her out by making a turn or two of this daily. Sometimes these attempts succeeded; just as often, the worm snapped under the strain. The consequences of this accident were often disastrous. Myriads of young escaped from the ruptured ends into the tissues, and violent inflammation and fever, followed by abscess and sloughing, ensued; weeks, or months perhaps, elapsed before the unhappy victims of this rough surgery were able to get about. Too often serious contractions and ankyloses from loss of tissue and inflammation, and even death from septic trouble, resulted.

If a guinea-worm be protected from injury, and the part she occupies frequently douched with water, her uterus will be gradually and naturally forced out inch by inch and emptied of embryos. Until this process is completed she resists extraction; possibly the hook at the end of her tail assists her to maintain her hold. When parturition, in from fifteen to twenty days, is completed, the worm is absorbed or tends to emerge spontaneously. A little traction, if practised then, may aid extrusion. Traction, however, must not be employed so long as the embryos are being emitted. The completion of parturition can be easily ascertained by the douching experiment already described.

Emily, a French naval surgeon, has introduced a system of managing guinea-worm cases which bids fair to shorten treatment and obviate the serious risks of the old winding-out system. By means of a Pravaz's syringe he injects the body of the worm, if she chances to be protruding, with solution of bichloride of mercury, 1 in 1,000. This kills the parasite; after twenty-four hours, extraction is usually easily effected. If the worm has not shown herself externally, but can be felt

coiled up under the skin, he injects as near the coils as possible, and through several punctures, a few drops of the same solution. This, too, kills the parasite. Her body is then absorbed, as a piece of aseptic catgut would be, without inflammation or reaction of any description; or she may be cut down on, and easily extracted. Others have confirmed the value of Emily's method, which saves much time and suffering and, with due care, is devoid of risk.

Prophylaxis.—From what has been stated with regard to the rôle of cyclops, it is evident that the prevention of guinea-worm is merely a question of protection of drinking-water from pollution by the subjects of guinea-worm infection. Leiper has shown that by raising by a few degrees the temperature of the water in which cyclops are living these crustaceans are killed. He suggests heating by a portable steam generator the water in wells and water-holes known to be sources of guinea-worm infection, as a prophylactic measure. Alcock has found that the addition of a trace of potash to the water is equally effective.

LOA LOA (Guyot, 1778)

Synonyms.—*Dracunculus oculi; Filaria loa; F. oculi, F. subconjunctivalis; F. diurna; F. bourgi.*

History.—*Loa loa* has been known for more than three hundred years. Although undoubtedly of African origin, the earlier described cases were in negroes in the West Indies who must have acquired their parasites in West Africa prior to their deportation as slaves to America. For long the worm was regarded as an immature dracunculus. Since the characters of the parasite have been more carefully studied this view can no longer be held, and *L. loa* is now thoroughly established as a distinct species.

In 1891 I found in the blood of two negroes—one from the lower Congo, the other from Old Calabar—certain microfilariæ morphologically closely resembling that of *F. bancrofti*, but differing from the latter inasmuch as they came into the peripheral circulation during the day and disappeared from it during the night. As in one of these negroes *L. loa*

had formerly been seen in his eye, I suggested that the new microfilaria, which I named *F. diurna*, was the hæmatozoal larval form of *L. loa*. This view was supported by the fact that in fragments of a loa which I received from Leuckart the contained embryos appeared to be identical in every respect with *F. diurna*. Nevertheless, I failed in several cases of *L. loa* infection to find *mf. diurna* in the blood.

In 1901, Dutton, Annett and Elliot had the opportunity of studying *F. diurna* in its own habitat in West Africa, and came to the conclusion that my hypothesis as regards the relationship of *F. diurna* and *L. loa* was erroneous, contending that *F. diurna* was none other than *mf. bancrofti* whose normal periodicity had been disturbed by the peculiar habits of those West African negroes who, they tell us, spent their nights in orgies.

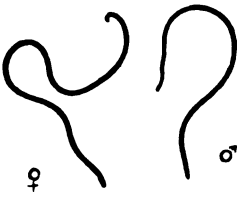


Fig. 143.—Loa loa (nat. size).

Sambon, refuting the theory of the Liverpool Commission, again pointed out the similarity of *mf. diurna* to the larvæ still contained within the uterus of *L. loa*, and explained that the lack of contemporaneousness between *mf. diurna* and *L. loa* in the same patient is probably due to the fact that this long-lived parasite does not produce its young until after a long period of wanderings, when, having attained full maturity, it retires into deeper structures for parturition. He pointed out that the majority of filariæ removed whilst wandering beneath the skin of patients were more or less immature forms; that in young children *L. loa* is, as a rule, the only form found, whilst in adults *mf. diurna* is the commonest finding, with frequently the history of a previous loa; and finally that *F. equina* of horses and asses, also found in or about the eyes of the host in its immature or barely mature stages, descends into the peritoneal cavity for parturition when fully mature.

Later, an association was discovered between

L. loa and the disease known as Calabar swellings, and, also, between Calabar swellings and *mf. diurna*. Moreover, as a considerable number of cases of *L. loa* concurring with *mf. diurna* have now been recorded by Prout, Henley, Brumpt, Wurtz, Penel, Kerr and myself, and as the concurrence of the geographical range of the two forms of parasitic infection has been fairly well made out, there can be little doubt that *L. loa* and *mf. diurna* are respectively the mature and larval form of the same species.

Geographical distribution.—We have no definite knowledge of the extent and details of the geographical range of *L. loa*. It appears to be widely distributed throughout tropical West Africa from Sierra Leone to Benguella. In some parts—as in Old Calabar, Cameroons, and the Ogowé River—a very large proportion of the inhabitants are affected. How far it penetrates into the interior of the continent is as yet unknown. I have seen several cases in Europeans from the Upper Congo within a few miles of Stanley Falls. Brumpt records its presence in Kassai, approximately 600 miles from the coast on one of the chief tributaries of the Congo. The larval form (*mf. loa*) has been found twice by Cook in Uganda, although such isolated findings cannot be taken as landmarks, seeing that *L. loa* is a long-lived parasite and its hosts may have contracted the infection years previously, and at a distance from the place at which it was recognized. At the time of the slave trade numerous cases were reported from the West Indies and South America, but always in negroes from Africa, and their occurrence ceased with the abolition of slavery. The suggestion that about 1795 there existed an endemic centre for this parasite in San Domingo is based on very doubtful evidence. Nowadays, cases are occasionally seen in Europe and America, in both negroes and whites, but only in persons who have frequented those parts of Africa inhabited by the parasite. Possibly, on account of the opening of new trade routes and of the more frequent intercourse between the natives, *L. loa* may greatly extend its range in Africa.

Zoological distribution.—Hitherto *L. loa* has not been seen by reliable observers in animals, but, according to Plehn, the natives of Cameroons assert that it occurs in goats and sheep.

The parasite (Figs. 144, 145).—*L. loa* is especially characterized among the nematodes of man by the presence of numerous rounded, smooth, translucent protuberances of the cuticle, 12–16 μ in diameter and rising 9–11 μ above the general surface. These chitinous bosses vary greatly in number and arrangement on different specimens and are, as a rule, more numerous on the female. Their distribution is very irregular. In the male they are wanting at the extremities, beginning about 1·5–2·5 mm. from the mouth and tail-tip respectively. In the female they usually extend to the posterior extremity and may also be found on the cephalic end.

The body is filiform, cylindrical, whitish, semi-transparent. Anteriorly, it tapers somewhat abruptly to the mouth, which is terminal, small, simple, unarmed, and apparently destitute of papillæ. There is no distinctly marked neck, but there is a sort of shoulder about 0·15 mm. from the mouth, and at about this level are two small papillæ, one corresponding to the dorsal, the other to the ventral median line.

The posterior extremity of the female is straight, attenuated, and broadly rounded off (Fig. 146). That of the male is slightly curved ventrally and provided with two lateral expansions of the cuticle (0·7 mm. long by 0·029 mm. broad), situated nearer the ventral than the dorsal surface. In the middle of the ventral surface, between the lateral alæ, and about 0·080 mm. from the tail-tip, is the opening of the ano-genital orifice, from which two unequal spicules may be seen protruding. The opening is surrounded by thick labia. On either side, and somewhat asymmetrically placed, are four large globular and pedunculated papillæ closely approximated and decreasing in size antero-posteriorly. Farther back, and nearer to the middle line, is a fifth symmetrical pair of very small, conical, postanal papillæ with broad base and acuminated point. (Fig. 147.) Leiper has reported the existence of three additional minute and paired papillæ.

The adult male worm measures 30–34 mm. in length, and presents a maximum breadth of 0·350–0·430 mm. in the anterior part of the body. The posterior part tapers gradually towards the tail. The measurements of the adult female have not been satisfactorily determined. The specimens so far examined, extracted from under the skin or from about the eyes of patients, varied greatly in length*—20 mm. (Blanchard); 27 mm. (Leuckart); 32·3 mm. (Manson); 50 mm. (Annett, Dutton and Elliot); 52 mm. (Looss); 55 mm. (Ozzard); 60 mm. (Brumpt); 70 mm. (Maurel).

* If the record of Guyon (1864) that his specimen was 15 cm. long does not rest on an error in transcribing or printing, it shows that the fully grown female is really much larger than we know at present from the extracted subcutaneous specimens.

The alimentary tube begins at the oral cavity, which is funnel-shaped and surrounded by a strong muscular mass. It consists of a slender œsophagus without bulb, of an intestine attaining a width of about 65 μ towards the middle of the body, and of a short, attenuated rectum.

The male reproductive organ is first encountered about 3 mm. from the cephalic extremity, where it ends in a pointed blind sac. Anteriorly it is very sinuous and winds round the alimentary canal; posteriorly it straightens, attains a diameter of 85–105 μ, and terminates by a vesicula seminalis filled with more or less spherical spermatozoa 6–8 μ in diameter.

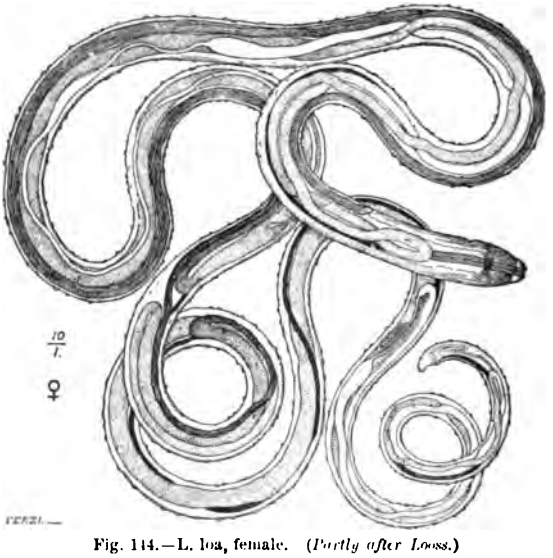


Fig. 144.—L. loa, female. (*Partly after Looss.*)

In the female the vulva forms a small eminence at about 2·5 mm. from the anterior extremity. The vagina, 9 mm. long and 95 μ wide, branches off into two long tubes extending almost throughout the entire length of the body. These tubes, the narrow ends of which are the ovaria, contain eggs in all stages of development, as well as free larvæ 0·253–0·262 mm. in length by 0·0047–0·005 mm. in breadth.

Structure of the larval form.—*Microfilaria loa* (= *diurna*) is very similar in size (298 μ by 7·5 μ) and structure to *microfilaria bancrofti*. Like the latter, it is enclosed within a "sheath," its tail is pointed, and it has the same V and tail spots. (Fig. 93.)

Their respective periodicities are very characteristic; more so, apparently, in the case of *mf. loa* than in that of *mf. bancrofti;* for, whereas by inverting the sleeping habits of a subject of *F. bancrofti* infection it is easy to invert or disturb the periodicity of the microfilariæ, this cannot be done in the case of *mf. loa.* Unfortunately, I can adduce only one experiment in support of this remarkable circumstance; but that experiment was a very thorough and carefully conducted one, and extended over a considerable period. During all the time the patient (who had had several *L. loa* excised at different times and who was still showing signs of their presence) slept during the day and kept awake during the night; nevertheless, the microfilariæ

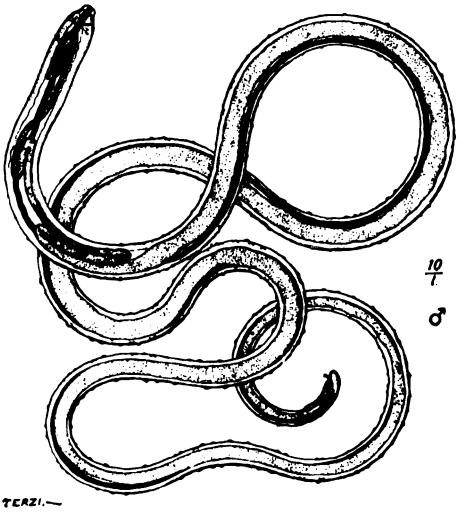


Fig. 145.--L. loa, male. (*Partly after Looss.*)

continued to appear in vast numbers in the peripheral blood during the day, but were only very rarely found in it during the night.

Although in the fresh liquid blood it is practically impossible to distinguish, with the microscope alone, the living *mf. loa* from the living *mf. bancrofti*, in dried and stained films certain more or less pronounced differences can be made out. (1) In such preparations *mf. bancrofti* is usually disposed in sweeping and graceful curves, such as a skilled penman might make (Plate XI., Fig. 1); *mf. loa*, on the other hand, assumes a stiff, ungraceful, almost angular attitude like the flourishes made by a schoolboy (Plate XI., Fig. 2). (2) The tail end of

mf. loa is often disposed in a series of sharp flexures, giving it in some instances a corkscrew-like appearance, the extreme tip being always sharply flexed. (Plate XI., Fig. 6) (3) The nuclei of the central column of cells of *mf. loa* are larger and stain less deeply than those of *mf. bancrofti*, and, as a rule, the cephalic end of the column is more abruptly terminated in the former. Although in most slides one or two specimens may be hard to diagnose, on the average of a series of preparations the foregoing distinctions are recognizable. Fülleborn by special staining methods points out various minor differences (*see* Fig. 98), amongst which the large genital cell is a marked feature. He proposes the measurement of various fixed points (Fig. 128) as a standard of differentiation of the various microfilariæ.

Life history.—Of the life history of *L. loa* little is positively known. As the larval form comes into the peri-

Fig. 146.—Posterior extremity of L. loa, female. (*After Looss.*)

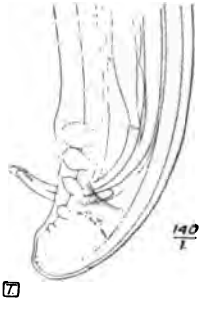


Fig. 147.—Posterior extremity of L. loa, male. (*After Looss.*)

pheral circulation of the human host, it is very probable that, like *mf. bancrofti*, it is liberated by some blood-sucking insect; and, seeing that it approaches the surface of the body only during the daytime, this must be a blood-sucker of diurnal habit.

Several years ago I called attention to the so-called mangrove flies as possible intermediaries, specifying as the most probable *Chrysops dimidiata* (Fig. 148). This conjecture Leiper has ascertained to have been well founded. During a recent visit to West Africa, with the object of ascertaining the intermediary host of *L. loa*, he examined many blood-sucking insects, including mosquitoes and a variety of other insects. He found that in *Chrysops dimidiata* and in *C. silacea* rapid and uniform developmental changes of *mf. loa* were effected, similar to those of *mf. bancrofti* in the mosquito, and that they took place in the salivary glands of the insect. As to the way in which *L. loa* is acquired we must await further information. It would

appear that, after it has entered the human body, development is very slow, and that probably full maturity is not attained until after several years. In many cases the parasite did not show itself until 3, 4 and 4½ years after the patient had left the endemic area. In one case the parasite was extracted from the eye 13 years after the patient had left Africa; in another the worm or worms appeared at irregular intervals during 15 years. Manifestly it is long-lived. An interesting and suggestive evidence of slow development is that, while the immature active worm is often seen in children, the larval form in the

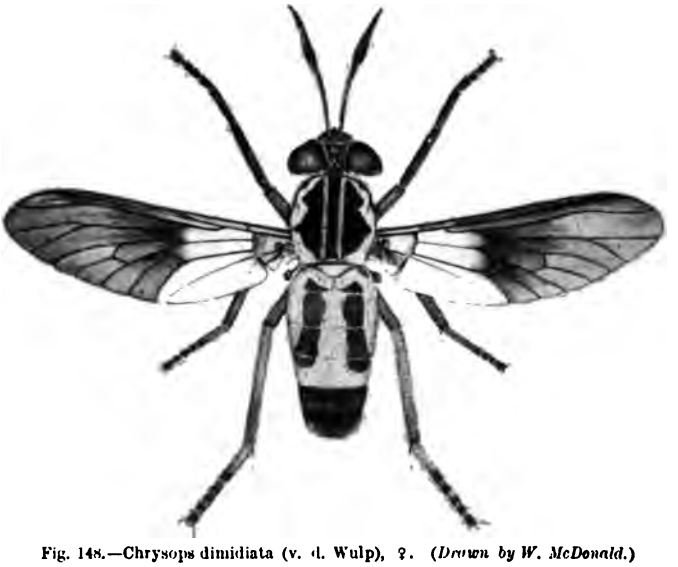


Fig. 148.—Chrysops dimidiata (v. d. Wulp), ♀. (*Drawn by W. McDonald.*)

blood is found as a rule only in adults. Annett, Dutton and Elliot, in 390 native children of all ages up to about 18 years, examined in a district where *L. loa* was exceedingly common in adults, found *mf. loa* once only in a boy (aged 11). Meinhof reports a case in which the period elapsing between infection with *F. loa* and the appearance of embryos in the blood was at least 7 years.

Slow development and a different habitat at different stages are not peculiar to *L. loa* only. *F. equina* of the horse and ass and *F. labiato-papillosa* of deer and cattle wander about the subdermal connective tissues and frequently occur in the eyes during their semi-adult stage, but repair to the peritoneal cavity when fully mature. The larvæ of both are found in

the blood of the respective hosts, and Noè has shown recently that *F. labiato-papillosa* is fostered and transmitted, like *F. bancrofti* and *F. immitis*, by an insect intermediary, to wit, the stinging-fly (*Stomoxys calcitrans*), amongst the cephalic muscles of which it undergoes development.

This slow development of *L. loa* would seem to account for the very frequent failure to find the microfilaria in the blood in cases in which mature parasites have been extracted, a circumstance which has been brought forward as an argument against the theory that *mf. diurna* was really the offspring of *L. loa*. Some time ago I was consulted by a lady who for seven years had been troubled with *L. loa* and Calabar swellings, and had had three loas removed at different times from the neighbourhood of the eye. On examining her day blood I found it full of innumerable specimens of *mf. diurna*. That these microfilariæ were *diurna* was fully established by a series of carefully conducted observations carried on day and night for upwards of a week. The patient informed me that she believed the medical man who seven years before had extracted one of the loas from her eye had probably the specimen in his possession still. This I had an opportunity of examining. It was a mature female crowded with embryos in all stages of development, including free larval forms such as were found in the blood. It transpired that I had already, many years before, examined this specimen, and that, being interested in the subject, I had written for specimens of the day blood of this patient soon after the extraction had been made. On referring to my note-book I found a record of the result of my examination of this blood, and that no microfilariæ were then found. From this it is evident that the mature *L. loa* may be present in the tissues, and yet that embryos may be absent from the blood. I cannot suggest an explanation of what is apparently an anomaly; but the fact is definitely ascertained, and explains how it is that in many of the recorded cases of loa infection the embryos have been absent from the general circulation. It may be that it is not until the gravid female arrives at some organ or tissue that she deposits her young in such a position that they can get access to the circulation, and that the wanderings for which these worms are so remarkable are an effort to attain this situation. It would be well for those who have the opportunity to look for the parasite at autopsies, especially in the serous cavities. Quite recently Penel stated that he had found *mf. loa* in the saliva and urine of a patient who presented this larval filaria in the peripheral circulation.

As yet it is impossible to estimate accurately the number of adult loas present in any given infection, although in advanced cases some idea of this might be got from the number of microfilariæ in the peripheral blood. As a rule it is safe to conclude that the particular loa that may show itself about the eye or elsewhere is only one of many. Thus, in 1903, Brumpt, at the post-mortem of a negro whose blood con-

tained microfilariæ (for which, under the impression that it was a new species, he suggested the name of *F. bourgi*), found in the tissues of the heart five adult worms. Four of these were cretified, but the fifth was alive and contained embryos similar to those in the blood. This worm he subsequently identified as a *L. loa*. In the following year Wurtz found *mf. diurna* in the blood of a Congolese negro suffering from sleeping sickness. On the death of the patient he made a most careful post-mortem examination, and found two adult loas in the subcutaneous connective tissue of the arm. On the dissection being continued by Penel, over thirty additional specimens, male and female, were discovered under the skin of the limbs. There are not a few instances on record in which two or more loas have been extracted from the same patient. We may, therefore, be practically certain that in nearly every instance of this kind of filariasis the infection is multiple.

There is evidence that after the death of *L. loa* calcification takes place, as in *F. bancrofti*.

Pathogenesis. — As already stated, *L. loa* during the period of its growth and development in man makes frequent excursions through the subdermal connective tissues. It has been noticed very frequently beneath the skin of the fingers, and it has been excised from under the skin of the back, from above the sternum, from the left breast, the lingual frænum, the loose skin of the penis, the eyelids, the conjunctiva, the anterior chamber of the eye. Ziemann says that it may wander about the scalp. The parts most frequently mentioned are the eyes, and, although the worm may have attracted more attention when in this situation, it seems as though it has a decided predilection for the eye and its neighbourhood. A patient informed me that the average rate at which a loa travelled was about an inch in two minutes. Both he and others have told me that warmth, such as in sitting before a fire, seemed to attract them to the surface of the body. As a rule, the migrations of the parasite give rise to no serious inconvenience, but they may cause prickings, itching, creeping sensations and, occasionally, transient œdematous swellings, "Calabar swellings," in different parts of the body. When the parasite appears under the conjunctiva it may cause a considerable amount of irritation and congestion; there may be actual pain even, associated with swelling

and inability to use the eye and, perhaps, tumefaction of the eyelids. Should a loa wander into the vicinity of such a situation as the rima glottidis or the urethra the consequences might be serious.

CALABAR SWELLINGS

Under this name Thompstone described certain fugitive swellings which are of frequent occurrence in parts of tropical West Africa—Southern Nigeria to Benguella and inland to the Upper Congo. They are found in natives and Europeans alike. I have seen many cases in Englishmen, especially in officials from the neighbourhood of Old Calabar. Thompstone says "the swellings are about the size of half a goose egg, painless, though somewhat hot, both objectively and subjectively, not pitting on pressure, and usually disappear in about three days. They come suddenly and disappear gradually, and occur in any part of the body." Thompstone never saw more than one swelling at a time. They recur at irregular intervals and, it may be, during many years after the patient has returned to Europe. In some instances the swellings seem to be induced by the rubbing provoked by the irritation accompanying the presence of a *L. loa* just under the skin, in other instances they develop spontaneously. When occurring in the hand, or about the forearm, they may give rise to a sensation of powerlessness and soreness as if the part had received a blow. They never suppurate.

Although in a large proportion of cases *L. loa* larvæ cannot be found, in others either the parent worm has shown itself on the eye, or its microfilariæ have been detected in the blood. The latter circumstance, together with the geographical feature of the endemicity of these swellings and their clinical characters, makes it practically certain that they are somehow produced by *L. loa*. On the supposition that the swelling might be caused by the emission of her larvæ by a parent loa into the connective tissue, I endeavoured in one case, by aspirating the centre of the swelling with a hypodermic syringe, to substantiate this speculation; the result was negative,

but a second attempt on another patient yielded great numbers of microfilariæ in the lymph abstracted. Notwithstanding this success it cannot be affirmed that the mechanism of the production of Calabar swellings has been solved.

ONCHOCERCA VOLVULUS, Railliet and Henry, 1910

Synonym.—*Filaria volvulus*, Leuck., 1893.

History.—*Onchocerca volvulus* was discovered by a German medical missionary, who noticed peculiar worms in two tumours the size of a pigeon's egg, which he had removed, one from the scalp, the other from the chest of Gold Coast negroes. The tumours were forwarded to Leuckart, who described and named the parasite *Filaria volvulus* in 1893. In 1899 Labadie-Lagrave and Deguy found an immature female filaria, which Blanchard identified as *O. volvulus*, in a small tumour removed from the arm of a soldier, who must have contracted the infection six years previously whilst campaigning in Dahomey. Labadie-Lagrave and Deguy were able to show that the parasite occupied a lymphatic vessel. In 1901 Prout described two cases from Sierra Leone. Brumpt, during his travels through Central Africa, had the opportunity of examining numerous cases. Recently Fülleborn and Parsons have added considerably to our knowledge of this parasite. Other species, such as *O. gibsoni*, are parasitic in cattle and give rise to small nodes in beef. It has been suggested by Cleland that this species is transmitted by *Stomoxys*.

Geographical distribution. — The earlier cases were reported from the West Coast of Africa —Sierra Leone, Gold Coast, Dahomey. Brumpt met with his cases along the Welle between Dongon and M'Binia. He believes that in that region *O. volvulus* affects about 5 per cent. of the riverine population. He saw cases on the Himbri, and he refers to others on the Kibali and on several of the tributaries of the Welle. Cooke met with cases in Uganda, Fülleborn in Cameroons, Parsons in Northern Nigeria.

The parasite.—According to Parsons, the adult male is 20–32 mm. in length by 0·2 mm. in breadth. The body is white, filiform, tapering at both ends. The head is rounded and has a diameter of 0·04 mm. The cuticle is transversely striated. The mouth is unarmed. The alimentary canal is straight and ends in a subterminal anus. The tail terminates in a single spiral, and is bulbous at the tip. There are two pairs of preanal papillæ, two pairs of postanal papillæ, and an intermediate single large papilla. Two unequal spicules may be seen protruding from the cloaca.

According to Braun, the adult female measures 60–70 mm. in length by 0·36 mm. in breadth; more recent measurements are much less, 35–40 mm. in length (Schäfer). The head is rounded and truncated; it measures 0·04 mm. in diameter. The tail is curved. The striations of the cuticle are not so distinct as in the male. The egg posesses a peculiar striated shell.

The larva measures about 300 μ in length; it has no "sheath." The body tapers from about the last fifth of its length and terminates in a sharply pointed tail. At about the anterior fifth of the body there is a gap in the central column of cells (V spot).

At least four males and two females are present in every tumour.

Pathogenesis.—*O. volvulus* is found in peculiar subcutaneous fibrous tumours, the size of a pea to that of a pigeon's egg. The same patient may present one or several of these tumours. The regions of the body most frequently affected are those in which the peripheral lymphatics converge. Thus the tumours are usually found in the axilla, in the popliteal space, about the elbow, in the suboccipital region, and in the intercostal spaces. They are never adherent to the surrounding structures and can be easily enucleated. They are formed of a dense mass of connective tissue, which enwraps the parasites and encloses small cyst-like spaces filled with a greyish viscous substance consisting almost entirely of microfilariæ. The position of the adult worms within these tumours is very remarkable. The greater length of their coiled-up bodies is embedded in the connective stroma, but the posterior extremity of the male with its copulating organs, and the anterior extremity of the female with its vaginal opening, are free and contiguous in one of the spaces.

The formation of the tumours is elucidated by Labadie-Lagrave and Deguy's case. These authors

found an immature female *O. volvulus* in a lymphatic vessel partly obstructed by an infiltration of fibrin and leucocytes. It appears, therefore, that the presence of the parasites within the lymphatics gives rise to an inflammatory process, and that the consequent fibrinous deposit envelops the parasites, obliterates the lumen of the vessel, and ultimately isolates the affected tract. According to the natives, the tumours may last indefinitely, and they seldom ulcerate or suppurate.* Some old patients told Brumpt that their tumours had been present since childhood.

Life history.—Nothing is known of the life history of this filaria. Recently, larvæ, presumably those of *O. volvulus*, have been found in the peripheral circulation by Fülleborn, Simon, Ouzilleau, and Rodenwaldt. Brumpt, from the examination of numerous sections of filarial tumours, is confident that the microfilariæ leave the cysts. He has seen them round the periphery of the tumours, and believes they may reach the lymphatics and thence the general circulation. He even suggests that the infection is transmitted by some blood-sucking insect, and, considering its riverine distribution, he points more especially to the glossinæ.

SPARGANUM MANSONI (Cobbold, 1883)

Synonyms.—*Ligula mansoni; Bothriocephalus liguloides; B. mansoni; Dibothrium mansoni.*

This parasite, the larva of a cestode belonging to the family Dibothriocephalidæ, and, provisionally, to the artificial collective group Sparganum,† was discovered in 1882 by the writer in making the post-mortem examination of a Chinese in Amoy. So far only the larval form is known, the size varying according to stage of development. The following measurements have been given: length, 8 to 36 cm.; breadth, 0·1 to 12 mm.; thickness, 0·5 to 1·75 mm. My own

* Schäfer has recently reported finding portions of undoubted *O. volvulus* in deep muscular abscesses, in the Cameroons.

† This group includes larval stages of bothriocephaloid worms which have not reached a stage of development enabling determination of genus.

specimens measured about 30 to 35 cm. in length, by about 2·5 mm. in breadth. During life they are extremely elastic, after immersion in alcohol they contract and wrinkle. The anterior end is broader than the posterior, is rounded, and presents a papilliform projection on which is found the compressed and more or less completely invaginated head. (Fig. 149.) The body is flat, unsegmented and transversely wrinkled. On the ventral surface there is, as a rule, a distinct longitudinal median groove; on the dorsal

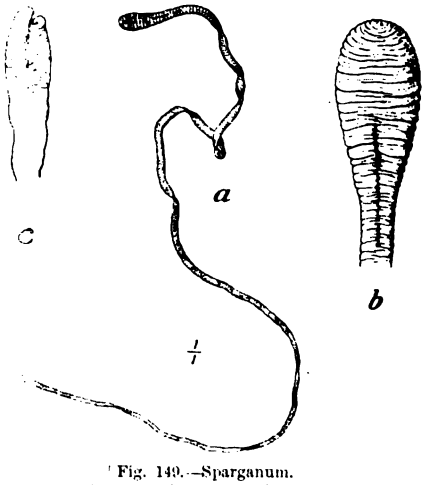


Fig. 149.—Sparganum.
a, Natural size; *b*, anterior extremity; *c*, posterior extremity. Extracted from an abscess in a Masai. (*After Sambon.*)

surface there may be two longitudinal grooves. No sexual organs are present.

In my case the parasites (11) lay under the peritoneum in the neighbourhood of the kidneys and iliac fossæ, and (1) apparently free in the pleural cavity. They were more or less coiled up and irregularly disposed in the subperitoneal fascia, looking like ribbon-strings of fat until turned out, when they exhibited feeble yet distinct movements. Scheube found a specimen in the urethra of a Japanese. Ijima and Murata also found the same parasite in the

urethra, the worm appearing during micturition with its head projecting from the urethra and occluding it. Thrice very young specimens have been found in Japan lying beneath the conjunctiva and producing swellings the size of a bean. In one of the Japanese cases the parasite was found in the subcutaneous connective tissue of the thigh, where during nine years it gave rise to indolent tumours that recurred fairly regularly every summer at about the same spot; it seemed to change its position very readily, disappearing in about ten days. At the time of its last appearance the swelling attained the size of a fist; an abscess formed from which the worm was extracted. A similar parasite, identified by Sambon, was likewise extracted from an abscess on the thigh of a Masai, in German East Africa, by Baxter; and another was found by Daniels in a Carib in British Guiana.

Nothing is known of the life history of this worm. Leuckart conjectures that the definitive host is probably a carnivorous animal closely associated with man, possibly the dog, the cat, or perhaps the pig. Looss believes that it is an aquatic animal (a bird or a fish), because the parasite appears to endeavour to leave the body of its intermediary host. Analogy and structure suggest that on entering the definitive host the body of the parasite disappears and a tapeworm strobila develops from the posterior part of the surviving head and neck, as in *Cysticercus fasciolaris* of the mouse, or in the plerocercoid of *Dibothriocephalus latus*.

SPARGANUM PROLIFERUM (IJIMA, 1905)

Synonyms.—*Plerocercoides prolifer*, *Plerocercus prolifer*.

History.—*Sparganum proliferum* has been reported but once, from Tokyo, Japan. It was found encysted in the subcutaneous tissue in man.

According to Ijima, who describes it, this larva (Fig. 150) may attain 1·12 mm. in length by 2·5 mm. in breadth. The anterior is narrower and more motile than the posterior end, and may exhibit an apical depression which possibly serves as a sucker. The body, with the exception of the head, contains a number of roundish calcareous corpuscles, and in older specimens there are also reserve-food bodies irregularly distributed. These larvæ can multiply by transverse fission. They give rise

ally such attacks come on without apparent cause. The hæmoptysis may be trifling; on the other hand, it may be so profuse as to threaten life—at all events, to cause intense anæmia.

The sputum.—On placing a minute portion of the viscid, pneumonic-like sputum under the microscope, its peculiar colour is found to be due partly to red blood-corpuscles, partly to a crowd of dark-brown, thick-shelled, operculated ova (Fig. 151). These ova

Fig. 151.—Ova of Paragonimus westermani in sputum.

vary a good deal in size and shape; they are all distinctly oval, have a yellow, smooth, double-outlined shell, and measure from 80 to 100 μ in length by 40 to 60 μ in breadth. If the sputum be shaken up in water, and the water be renewed from time to time, in the course of a month or six weeks—longer or shorter according to temperature—a ciliated embryo (miracidium) is developed in each ovum. When the ovum is mature, on placing it on a slide and exercising slight pressure on the cover-glass the

operculum will be forced back, and the miracidium will immediately emerge and at once begin to swim and gyrate in the water. Farther than this the life history of the larva has not been traced; but, doubtless, it is continued in some fresh-water animal, through which it finds its way back, in a more or less direct way, to man.

Pathological anatomy.—On making a section of the lungs in this disease, a larger or smaller num-

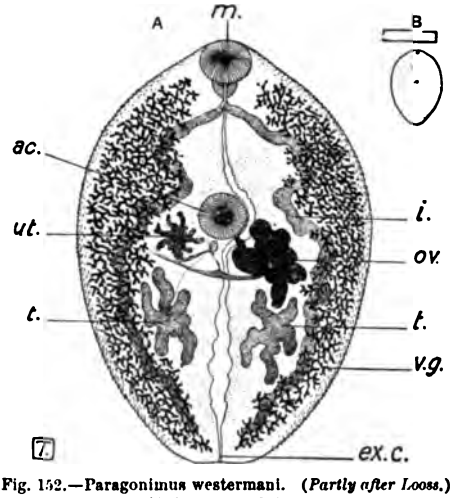


Fig. 152.—Paragonimus westermani. (*Partly after Looss.*)
A, Magnified; B, natural size. (*See* text.)

ber of what are known as "burrows" are discovered scattered about this organ, particularly towards the periphery. These burrows consist of areas, somewhat larger than a filbert, of infiltrated lung tissue in which can be seen a number of tunnels filled with the same material that constitutes the characteristic sputum, and also containing one, two, or more small trematodes. The septa between the tunnels may break down and a considerable cavity be thus produced; and as this occurs in connection with one of the bronchi, with which the tunnels always

communicate, it may give rise to the appearance of a dilated bronchus. One burrow may communicate with another.

When first discovered it was supposed that *P. westermani* was confined to the lungs. We now know that it may affect the liver, peritoneum, testes, intestine, skin, muscle, and brain. In the brain it forms a sort of tunnelled tumour similar to those in the lungs, and by the pressure or irritation proceeding from this tumour may give rise to a peculiar and ultimately fatal form of Jacksonian epilepsy.

The parasite (Fig. 152).—The parasite itself is reddish brown in colour, thick and fleshy, and oval in form. So thick is it that its transverse section is almost round. It measures 8 to 16 mm. in length by 4 to 8 mm. in breadth, and is covered with broad scale-like spines. The anterior extremity is bluntly rounded and without cephalic cone; the oral sucker (Fig. 152, *m*) (0·88–1·12 by 0·80–0·83 mm.) terminal or sub-terminal; ventral sucker (Fig. 152, *ac*) (0·88–1·2 by 0·86–1·44 mm.) slightly larger than the oral sucker and situated somewhat anteriorly to the middle of the body, The pharynx is elongate, but the œsophagus is very short. so that the bifurcation of the intestine is considerably anterior to the ventral sucker. The intestinal cæca (Fig. 152, *i*) run somewhat zigzag to the caudal end of the body. The genital pore opens close to the posterior margin of the ventral sucker. The testes (Fig. 152, *t,t*) are tubular, ramified, and situated on each side of the middle line, one slightly posterior to the other. The ovary (Fig. 152, *o*) is branched and is placed somewhat posteriorly to the ventral sucker, and either to the right or left of the middle line. The shell gland is lobate; the uterus (Fig. 152, *ut*) short and usually massed; the vitellaria (Fig. 152, *vg*) are marginal and greatly developed.

Diagnosis.—Diagnosis of endemic hæmoptysis is at once established by the discovery of the characteristic ova in the almost equally characteristic sputum. Râles and other physical signs of lung consolidation are not usually discoverable. If the intestine or liver is implicated, ova may appear in the stools.

In the case of one-sided convulsions, or in hemiplegic affections occurring in a native of or in a visitor from the countries in which this trematode is endemic, the sputum should be examined on the chance of discovering evidence of the parasite. Should

ova be found, there is a strong presumption that the cerebral trouble arises from trematode tumour in the brain.

Treatment.—Hitherto no means of expelling this parasite from the lungs has been discovered. In the case of cerebral distomatosis it might be possible by an operation to remove the parasite and associated tumour, and thus afford a chance of recovery in what has hitherto proved a fatal condition.

Prophylaxis in this, as in so many animal parasitic diseases, principally lies in the direction of securing a pure water-supply for drinking and bathing purposes, and avoiding all uncooked articles of diet which might be supposed to contain the young parasites. The sputum should be destroyed.

NOTE.—Musgrave (*Philippine Journal of Science*, March, 1907) has recently shown that paragonomiasis is not uncommon in the Philippines. He met with 17 cases in one year. He gives a detailed account of the pathological anatomy of this helminthiasis, bringing out especially the important fact that in a proportion of instances the infection is of a general character, the peculiar bluish cyst-like burrows of the parasite occurring in many organs and tissues. The infiltration of the tissues by the eggs produces, especially in serous membranes, little brownish-red patches, sometimes quite visible to the naked eye. The intestinal submucosa is a common seat of infiltration, and here the presence of the ova may give rise to inflammatory reaction, ending, perhaps, in ulceration and in the appearance of ova in the stools.

In reading Musgrave's paper I was particularly struck by the statement that in one of his cases he found no fewer than 100 mature parasites congregated in a psoas abscess. It is usually believed that the flukes enter their vertebrate hosts as cercariæ, and that they at once proceed to their permanent habitat and to sexual maturity. If this be the case with *P. westermani*, it is difficult to understand how, without any special anatomical lead, so large a number as 100 cercariæ contrived to arrive at exactly the same spot. It seems to me that this local accumulation of adults could be best explained on the supposition that the infection of the patient took place at some earlier period in the development of the parasite, either in the miracidium, or in the redia stage, as Miyagawa has shown to occur in the case of *S. japonicum*.

CHAPTER XLIV

IV. PARASITES OF THE LIVER

OPISTORCHIS NOVERCA, Braun, 1903

Synonyms.— *Distoma conjunctum; Paropistorchis caninus* (Barker, 1912).

History. — *Opistorchis noverca* was discovered by MacConnell at Calcutta in 1876. Lewis and Cunningham, who a few years previously had found a similar parasite in the liver of pariah dogs from the same locality, suggested that both their own species and MacConnell's were identical with the *D. conjunctum* (now called *Metorchis conjunctus*) found by Cobbold in the liver of an American fox (*Canis fulvus*) that died in London. In 1903 Braun showed that the Indian trematode belongs to a different species, and gave it the name of *Opistorchis noverca.*

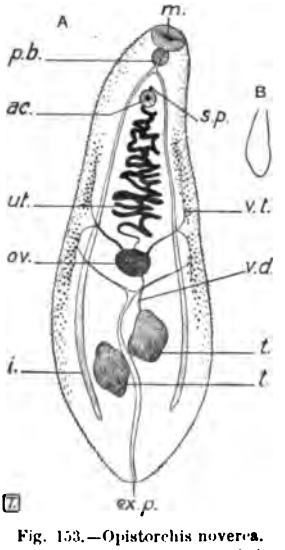


Fig. 153.—Opistorchis noverca.
A, Greatly magnified; B, natural size. (*See* text.)

Geographical distribution.—India.

Zoological distribution.—As stated above, it has been found in the gall-ducts of the dog (*C. familiaris*).

The parasite.—The description of the parasite is chiefly from the data and drawings furnished by MacConnell, and needs revision. *O. noverca* is of a lanceolate shape, and

more attenuated anteriorly than posteriorly. It measures from 9 to 12 mm. in length by 2·5 mm. in breadth. The oral sucker (Fig. 153, *m*) is terminal and larger than the acetabulum or ventral sucker (Fig. 153, *ac*), which is situated close to it, just below the bifurcation of the intestine. The cuticle is densely covered with spines. The pharynx (Fig. 153, *ph*) is large and globular; the intestinal cæca extend to about the posterior eighth of the body. The testes (Fig. 153, *t,t*) are in the posterior third and somewhat apart. The anterior one is roundish, the posterior one lobate. The ovary (Fig. 153, *ov*) is placed at about the middle of the body. The uterus (Fig. 153, *ut*) appears to be poorly developed, its convolutions spreading laterally barely beyond the cæca. The vitellaria (Fig. 153, *vt*) appear to extend from acetabulum to posterior testicle. The eggs are oval and measure 34 μ by 19 to 21 μ.

Pathogenesis.—Only a very few cases have been reported. In two, described by MacConnell, the parasites were found in large numbers in the bile-ducts, which were thickened and sacculated.

CLONORCHIS SINENSIS (Cobbold, 1875)

Synonyms. — *Distoma sinense; D. spathulatum; D. japonicum; D. innocuum; Opistorchis sinensis; Clonorchis endemicus.*

History.—*Clonorchis sinensis* was discovered almost simultaneously by MacConnell in India and MacGregor in Mauritius, in 1874.

Geographical distribution.—It has been found in many Eastern countries, including India, Mauritius, Japan, Korea, Formosa, China and Tonkin. In the last-named country it appears to be very common. In Central Japan, according to Katsurada, there are certain districts in which it affects from 56 to 67 per cent. of the population.

The parasite.—*C. sinensis* (Fig. 154) measures from 10 to 20 mm. in length, by 2 to 5 mm. in breadth; it is oblong, narrow, flat and somewhat pointed anteriorly, reddish in colour, and nearly transparent. The oral sucker is larger than the ventral acetabulum, which is situated almost on the border between the first and second fourths of the body. The cuticle has no spines. The pharynx is globular and short (Fig. 154, *ph*), the œsophagus is slender and 0·17 mm. long. The bifurcation of the intestine is nearer to the oral than to the ventral sucker. The intestinal cæca are simple, slender, and extend almost to the posterior end of the body. The genital pore opens on the middle line immediately in front

of the acetabulum. The testes are branched and situated in the posterior portion of the body, one behind the other. The ovary is trilobate and anterior to the testes. The uterus is moderately developed, and its coils are anterior to the genital glands. The vitellaria are moderately developed and occupy about the middle third of the body. The eggs are 28 to 30 μ in length by 15 to 17 μ in breadth, operculated, almost black in colour, and contain a ciliated embryo. Nothing is known of the life history of the parasite further than that it may occur in some of the lower animals—in the cat, for example. Probably its immature stages are passed in a mollusc or other small, soft-skinned, fresh-water animal. According to Yokagawa, cercariæ of this species are found in Japan in fresh-water fish of the family Cyprinidæ.

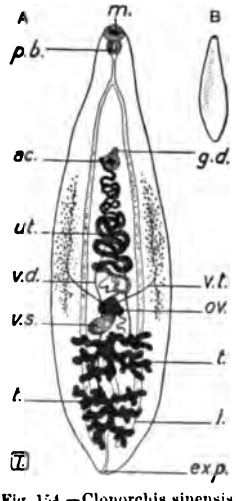


Fig. 154.—Clonorchis sinensis. (*Partly after Looss.*)

A, Magnified; B, natural size. (*See* text.)

Pathogenesis.—*C. sinensis* inhabits the bile-ducts and gall-bladder. It thickens the biliary canals and expands them in places into cavities and diverticula as large as filberts. In these cavities vast numbers of parasites may be found. The diverticula communicate with the bile-ducts, along which the ova of the parasites, and sometimes the parasites themselves, escape into the intestine. The affected liver is enlarged as a whole, although the tissue in the immediate neighbourhood of the diseased bile-ducts is atrophied. The spleen, also, may be hypertrophied, and the intestine in a condition of chronic catarrh. Some instances are recorded of the presence of this trematode in the pancreatic ducts, in the duodenum, and in the stomach.

This parasite, which for long was supposed to be practically innocuous, is now held to be the cause of a serious disease of the liver, which may terminate fatally; indeed there can be no doubt of this when

one considers that in some of the cases recorded several thousand parasites were present. However, we should not forget possible confusion with another grave distomatosis of Japan and other Eastern countries due to *Schistosomum japonicum*.

When the infection is severe the liver becomes enlarged, and chronic diarrhœa, with recurring attacks of jaundice, sets in. Later, anasarca appears and gradually a cachexia, resembling that of sheep-rot, is established, which, in the course of several years may prove fatal.

It would be well to bear this parasite in mind in approaching the diagnosis of obscure hepatic disease associated with diarrhœa and jaundice in patients from the East. It is just possible that the discovery of the ova in the stools might guide to a correct diagnosis.

Treatment.—So far no specific treatment has been found for this disease. The patient should be removed to a non-infected area and given nourishing food. Recently salol has been reported as beneficial in the analogous liver-fluke disease of sheep.

CLONORCHIS ENDEMICUS (Baelz, 1883)*

Synonym.—*Distoma japonicum* (R. Blanchard, 1886).

This trematode is found in Japan, where it is common in man, and in cats, dogs, and pigs. It is smaller than *C. sinensis*, 6–13 mm. in length by 1·8–2·5 mm. in breadth. There are no pigment granules in the parenchyma.

Kobayashi has found cats commonly infected with this parasite; he has also found an encysted distome in the muscles of certain fresh-water fish, especially near the villages of Kogo and Sanban, near Okayama. Eggs of this distome are found in the fæces of kittens one month after they have been fed on the flesh of such fish. On dissection of these kittens numerous adult distomes were found in the bile-ducts, gall-bladder, hepatic ducts, pancreas, and even in the

* According to Leiper, *C. endemicus* is not a distinct species but only represents a small form of *C. sinensis*.

duodenum. Kobayashi was also able to infect rabbits and guineapigs in the same way. Twenty-two days after the first infection the distomes were found to be mature and to contain eggs. In the younger stages the worms possess spines which are deciduous.

The fish act only as the second intermediary host; the first intermediary host still remains to be found.

Pathogenesis.—Lesions similar to those caused by *C. sinensis* are attributable to *C. endemicus*, together with a grave cachexia characterized by enlargement of the liver, diarrhœa, and ultimately anasarca.

Prophylaxis.—Manifestly the Japanese habit of eating raw fish is to be deprecated. Animals and men harbouring the parasite should be prevented from fouling water—whether used for drinking, bathing, or for agricultural purposes.

POROCEPHALUS ARMILLATUS (Wyman, 1848)

Synonyms.—*Linguatula armillata; L. constricta; Pentastomum constrictum; P. polyzonum; P. diesingi; P. euryzonum; Nematoideum hominis.*

History.—The larval form of this vermiform arthropod, belonging to the family *Linguatulidæ*, genus *Porocephalus*, was discovered in 1847 by Pruner, who found it, in Cairo, in the livers of two negroes. It must have been found in man before that date, since Pruner himself informs us that he saw two specimens in the Pathological Museum of Bologna, labelled "Insects from the liver of man." Subsequently it was found in man by Bilharz, Fenger, Kearney, Crawford, Marchoux, Chalmers and others. In 1852 von Siebold proposed to call it *Pentastomum constrictum*; but Shipley, in his revision of the family *Linguatulidæ* (1898), points out that the adult form was discovered and named *Linguatula armillata* in 1848 by Wyman, who found it in the lungs of an African python. Shipley further considers that Hoyle's *Pentastomum protelis* from the aard-wolf (*Proteles cristata*), Wedl's *P. leonis* from the lion, Van Beneden's *P. diesingi* from the mandrill (*Cynocephalus mormon*), and Hartley's *P. polyzonum* from an African python, belong to the same species. He also states that, in accordance with the rules of zoological nomenclature, the generic name for the cylindrical *Linguatulidæ* should be *Porocephalus*, a term introduced by Humboldt eight years before Rudolphi proposed the name *Pentastomum*. Neumann (1899) refers the larval forms found in man to *Porocephalus moniliformis*, a species discovered by Diesing in 1836 in the Indian python (*Python molurus*). Looss (1905) is of opinion that Wyman's and Diesing's species are identical. Sambon agrees with Shipley's

determination, based principally on the number of rings, which are never more than 22 in *P. armillatus*, but 28 to 30 in *P. moniliformis*.

Geographical distribution.—*P. armillatus* seems to be confined to tropical Africa, and hitherto, as regards man, to negroes only, among whom it is far from being uncommon. Dr. Salm has found a porocephalus encysted beneath the serous coat of the small intestine of a Djambi native in Java. He gives no description, but mentions it under the name *Porocephalus moniliformis*, together with similar parasites found in the Indian civet and in the tiger.

Zoological distribution.—The adult form inhabits pythons and other snakes. It has been found in *Python sebæ* by Wyman, Sambon and others; in the royal python (*Python regius*) and in the nose-horned viper (*Bitis nasicornis*) by Sambon. The larval—or, more correctly, the nymphal—form has been found in the lion, in the leopard, in the mandrill, in the aard-wolf. Pruner found it in the giraffe, Looss in Syke's monkey (*Cercopitheeus albigularis*), and Sambon in the Pousargues guenon (*Cercopithecus pousarguei*) and in the African hedgehog (*Erinaceus æthiopicus*).

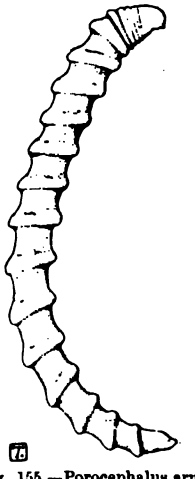


Fig. 155.—Porocephalus armillatus, natural size. (*After Sambon.*)

The parasite (Fig. 155).—Body vermiform, yellowish translucent, larger in females (9–12 cm. long by 5–9 mm. broad) than in males (3–4·5 cm. long by 3–4 mm. broad); cylindrical in the anterior half, slightly tapering posteriorly, and terminating in a blunt-pointed cone. It is characterized by the presence of prominent opaque rings 1–2 mm. wide, numbering 16 or 17 in the males, 18 to 22 in the females, placed somewhat obliquely and separated by interannular spaces 2–5 mm. wide except between the first rings, which are faintly indicated by shallow linear furrows. There is no clear distinction between cephalothorax and abdomen, and the rings nearest the cephalothorax are sometimes so indistinct that it is almost impossible to make out their actual number. The cephalothorax is depressed, slightly convex on the dorsal surface, more or less concave on the ventral surface. It is rounded anteriorly; posteriorly it is limited by the first body rings. It varies considerably in length; its breadth is from 4 to 7 mm. The mouth, opening on its ventral surface about 1 mm. from the anterior border, is lipped by a chitinous

ring. Above it are two prominent papillæ. On either side of the mouth are two protractile chitinous hooks similar in shape to feline claws. The anus is terminal at the posterior end. The genital orifice of the male is at the anterior end of the abdomen in the middle of the ventral surface of the first body ring; that of the female opens in the middle of the ventral surface of the caudal cone at about 1 mm. from the anus. The female is oviparous; the eggs are broadly elliptical.

The nymphal form (Fig. 156) is usually found spirally coiled within a cyst, the ventral surface corresponding as a rule to the convexity of the curve. In shape and structure the nymph closely resembles the adult, and the number of rings is the same. Calcification of the nymphal form in the liver may take place.

Life history.—Little until lately was known of the life history of *P. armillatus*; it is similar to that of the European linguatulid (*Linguatula tænoides*), which is also an occasional parasite of man. The ova, disseminated by snakes harbouring the adult form, reach the intermediary host probably with its food or drinking-water.* The larvæ then penetrate the mucosa, where some remain (Fülleborn); others pass on and become encysted in almost any organ or tissue, more especially liver, mesentery, or lungs. At a certain stage of development they escape from their cysts and migrate to the serous cavities, where they cause considerable inflammation. As a rule at this stage they are swallowed by their definitive host.

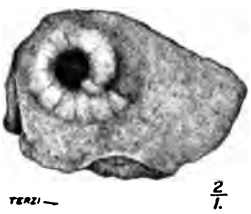


Fig. 156.—Nymph of Porocephalus armillatus. (*After Sambon*).

Pathogenesis.—There is much uncertainty as to the pathogeny of this parasite. Some consider it quite harmless. There can be no doubt as to the gravity of a heavy infection at the time when the parasites are migrating in their intermediary host. In Kearney's case, reported by Aitken, twenty or thirty parasites were found encysted in the liver and one or two in the lungs. The lungs were greatly congested. In Marchoux and Clouard's case the parasites were found in the liver and in the mesentery all along the intestine, but especially

* Experimental work has been done in this direction by Broden and Rodhain, who gave porocephalus eggs in drinking-water to sleeping-sickness patients in whom post mortem the larvæ were found encysted in the liver. Fülleborn fed two monkeys on eggs obtained from tracheal mucus of an infected python: one monkey died after 60, the other after 300 days, enormous numbers of encysted larvæ being found in every organ of the body. Twelve snakes were fed on the monkeys' bodies: one developed adult porocephali in the lungs, the larvæ having bored their way through the stomach wall.

about the cæcum. In Chalmers' case numerous parasites were found moving freely in the abdominal cavity over the surface of the various organs. A large number were found within the lumen of the small intestine. Many were still encysted in the lungs.

The diagnosis of porocephalus infection is impossible.

GIGANTORHYNCHUS MONILIFORMIS (Bremser, 1911)

This is a common parasite of the rat in many parts of the world. Christopherson found one specimen in the intestine of a Soudanese. It is a white parasite with attenuated extremities, with many rings, resembling a porocephalus. The male is 4–5 cm., the female 7–10 cm. in length.

CHAPTER XLV

V. INTESTINAL PARASITES

1. NEMATODES

Microscopical examination of the fæces for ova of intestinal parasites.—If the fæces of the natives of warm climates, and of Europeans coming from warm climates, are systematically examined with the microscope, in a large proportion of cases they will be found to contain the ova of one or other of three species of nematode worms—*Ascaris lumbricoides*, *Trichiuris trichiura* (*T. dispar*), and *Ankylostomum duodenale*. The ova of the tapeworm and of the common thread-worm (*Oxyuris vermicularis*) are

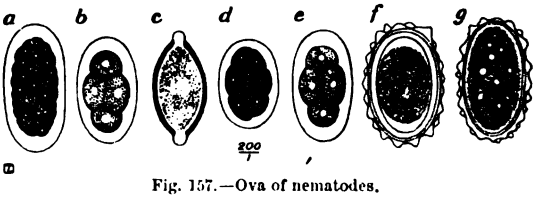


Fig. 157.—Ova of nematodes.

a, Strongylus subtilis; *b*, Ankylostomum duodenale; *c*, Trichiuris trichiura; *d*, Strongyloides stercoralis; *e*, Necator americanus; *f*, Ascaris lumbricoides; *g*, Ascaris lumbricoides (unfertilized).

rarely found in the stools, as these parasites do not, as a rule, part with their ova until the joints of the former, or the entire body of the latter, have left the alimentary canal; but as the three nematodes first mentioned pass their eggs directly into the bowel, these eggs habitually appear in the fæces and constitute unequivocal evidence of the presence of their respective parental forms. Occasionally the ova of hepatic and intestinal parasites—such as *Schistosomum japonicum*, *S. mansoni*, *Clonorchis sinensis*, *Fasciola hepatica*, *Fasciolopsis buski*, and other rare helminths are encountered; as these, with the exception of schistosomum, are very rare, from a practical point of view they may be disregarded. Without large experience the ova of the rarer parasites cannot be identified off-hand; but if the practitioner has learned to recognize those of the three common species, he will at once know when he comes across the ova of any of the rarer species, and, on referring to some special work on helminthology, will have little difficulty in arriving at a correct diagnosis.

The microscopical examination of fæces for ova, though somewhat disagreeable, is by no means a difficult matter. All that is necessary, by way of preparation, is to place on the slip a minute portion of the suspected fæces—about the size of a hemp-seed—and then to apply the cover-glass, gently gliding it over the slip so as to spread out the mass in a thin, fairly uniform, and transparent layer. If the bit of fæces prove too consistent, a little water may be added so as to soften it. If the stools are loose and watery, the sediment should be taken up with a pipette and examined. It is well to make two or three preparations. The microscopical examination must, in the first instance, be made with a low power—an inch, or better, a half-inch objective. Search must be made in every part of the slide, and every suspicious body carefully scrutinized, a higher power being used if necessary. A very little practice suffices for the identification not only of the commoner ova, but of the species of parasite to which the ova belong.

The points to be attended to in the diagnosis of ova are

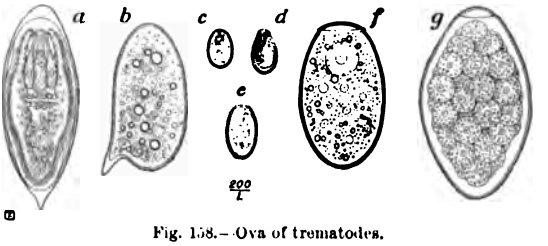


Fig. 158.—Ova of trematodes.

a, Schistosomum hæmatobium; *b*, S. mansoni; *c*, Heterophyes heterophyes; *d*, Opistorchi sinensis; *e*, Opistorchis noverca; *f*, Paragonimus westermani; *g*, Fasciolopsis buski.

size, shape, colour, thickness, roughness, smoothness, and markings on the surface of the shell; the presence or otherwise of yolk spheres, of a differentiated embryo, or, in the case of the cestodes, of the three pairs of embryonic hooklets; the existence of an operculum in the case of certain trematodes and of the broad tapeworms (*Dibothriocephalus*). The ova of the same species of parasite vary but slightly, and are in every instance sufficiently stable and definite for correct diagnosis.

Ova of Trichiuris trichiura (Fig. 157, *c*).—Of the three common nematodes mentioned—*Trichiurus trichiura*, *Ascaris lumbricoides*, and *Ankylostomum duodenale*—the ova of the first are the most frequently met with. They occur sometimes in enormous numbers, as many as six or eight specimens being visible in one field of an inch objective. They form a rather striking object under the microscope. They are oval, measuring from 51–54 μ by 21–23 μ, the ends of the long axis of the oval being slightly pointed and tipped with a little shining projection or plug. Their general appearance suggests an

elongated oval tray, the projections at the poles of the ovum representing the handles of the tray. They are dark brown in colour, sharply defined, doubly outlined, and contain no differentiated embryo.

The ova of *Ascaris lumbricoides* (Fig. 157, *f*, *g*) are considerably larger (60 to 75 μ by 40 to 58 μ) than those of trichiuris (Fig. 157, *c*). They are also, as a rule, more spherical, or, rather, more broadly oval; occasionally they are almost barrel-shaped. Like those of trichocephalus, they are dark brown in colour from bile-staining, but they are much less sharply and smoothly defined, possessing a coarse thick shell which is roughened by many warty excrescences. The yolk contents are not always easily made out, nor, when made out, can any sign of embryo or segmentation be discovered.

In certain instances, supposed to be unfertilized, the ova are smooth on the surface, the rough outer layer being almost or altogether absent.

A point of practical importance to be attended to lies in the circumstance that the rough outer layer on the shell of the ovum of ascaris is very easily detached, leaving the egg with a sharp, smooth outline suggestive of some other species of parasite. To obviate this, in mounting fæces it is well to avoid too much gliding of the cover-glass over the slip.

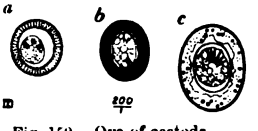


Fig. 159.—Ova of cestoda. (*After Looss.*)
a, Tænia solium; *b*, Tænia saginata; *c*, Hymenolepis nana.

The ova of *Ankylostomum duodenale* (Fig. 157, *b*) contrast very markedly with both the foregoing, particularly in the matter of colour. Trichocephalus and ascaris ova are invariably dark and bile-stained; those of the ankylostomum are beautifully clear and transparent; they measure 55 μ to 65 μ by 32 μ to 43 μ; have a regular, somewhat elongated oval form, with a delicate, smooth, transparent shell, through which two, or four, or eight light-grey yolk segments can be distinctly seen. It is well to search for these ova soon after the fæces have been passed; otherwise, owing to the rapidity with which, in favourable circumstances, development proceeds, the embryo may have quitted the shell and the egg be no longer visible.

TRICHIURIS TRICHIURA (L.)

Synonyms.—*Ascaris trichiura; Trichocephalus hominis; T. dispar.*

Trichiuris trichiura, the whip-worm (Fig. 160), lives chiefly in the cæcum. In many countries it is present in more than half the population. It is believed to maintain its position by transfixing, pin-fashion, with its long slender neck, a superficial fold of the mucous membrane. Wichmann claims to have shown, by serial sections of the cæcum at sites where

the parasites were fixed, that it is merely embedded in the mucus between the intestinal villi. According to Powell, the females very much preponderate, the proportion to males being as 466 to 1. Except that the practitioner should be familiar with the appearance of its eggs in the stool (Fig. 157, *c*), so that he may be able to distinguish them from those of ascaris, of ankylostomum, and of other parasites, the presence of *T. trichiura* is of no practical moment. So far as known, it gives rise to no serious pathological lesion; a fortunate circumstance, seeing that hitherto it has been found impossible, with any degree of certainty, to dislodge it by anthelmintics.

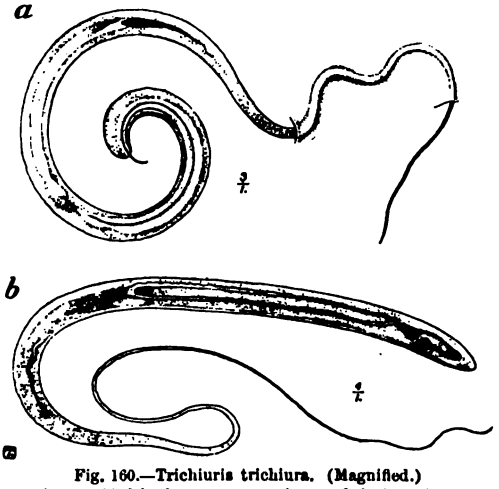


Fig. 160.—Trichiuris trichiura. (Magnified.)
a, Male partly embedded in the mucous membrane of the intestine; *b*, female.

ASCARIS LUMBRICOIDES (L.)

Though not quite so common in tropical countries as trichiurus, the ascaris is nevertheless very common indeed, especially in children, who often harbour these loathsome creatures in enormous numbers —in dozens, or even in hundreds. In those countries, at one time or another, nearly every child gets them; so much so that, when doubt exists about the nature of some obscure affection, a dose or two of santonin often produces results which will seem to justify a diagnosis of "worms," and, for the time being, perhaps satisfy an anxious mother.

Mode of infection.—The reason for the great frequency of *Ascaris lumbricoides* in tropical countries is probably twofold—the warmth of the climate, and the habits of the people with regard to the disposal of night-soil. In the fæces the ova exhibit no trace of segmentation or of differentiated embryo; but if placed in water, or kept moist and in a warm place, in the course of five or six months—longer or shorter according to temperature—the embryo is developed, and can be seen coiled up and moving about inside the egg-shell. If such an egg is accidentally or intentionally swallowed, on arrival in the stomach the shell is dissolved away and the contained embryo is set free. In a month it grows into a sexually mature animal, and, if both sexes are present, eggs in countless numbers are soon produced and appear in the fæces. Desiccation of the egg at atmospheric temperatures does not destroy the embryo, which will quickly revive on becoming moistened. In many warm countries night-soil is the favourite fertilizer, and is regularly collected and spread upon the fields. In this way the ova of ascaris obtain an opportunity of maturing, and thus, too, they have an opportunity of being swallowed by man. They may also be washed into drinking-water; or, becoming desiccated on the drying up of the fields, be blown about as dust; or they may become attached to fruit or vegetables. In one of these, or in similar ways, they finally reach the human stomach and there attain maturity.

Symptoms.—In many instances the ascaris gives rise to no very noticeable symptom; in other instances it is to be credited with a number of ill-defined gastric and perhaps nervous troubles—capricious appetite, foul breath, restless sleep, peevishness, vague abdominal pains, nausea, and so forth. Sometimes the worms get into the stomach and are vomited, their appearance giving rise to no inconsiderable alarm. They may even creep up the œsophagus and into the mouth, or out by the nostrils. Cases are on record in which they caused suffocation by wandering into the rima glottidis. They have been

known to enter the bile-ducts and give rise to jaundice; to penetrate the intestinal wall and escape into the peritoneum, causing peritonitis; or to burrow into the abdominal walls and cause abscess. Fortunately these accidents are of rare occurrence; their possibility, however, should be borne in mind, and, apart from other obvious considerations, ought to make us endeavour to rid patients of these troublesome guests as soon as possible. With this object in view, it was my practice in China to give my little patients, as a matter of routine, a few doses of santonin twice a year; very often the precaution received its justification by the appearance of one or more ascarides in the stools.

Adults, especially young adults, although to a much smaller degree than children, are liable to entertain these verminous visitors. Sometimes certain obscure dyspeptic symptoms in grown-up people will resist all treatment until three or four grains of santonin and a purgative have been administered. I had a patient once who for a long time had been troubled with unaccountable nausea. One day, while he was sitting at breakfast, the feeling of sickness came on with unusual intensity. He had to leave the table, and, after one or two retching efforts, brought up an *Ascaris lumbricoides*. After this he was no more troubled with nausea. It is well, therefore, when puzzled over some obscure dyspeptic condition in tropical patients, to bear the ascaris in mind. If, for some reason, it is undesirable to give santonin unnecessarily, the stools ought first to be examined with the microscope. If ova (Fig. 157, *f*, *g*) are found, a dose or two of santonin may clear up the diagnosis and cure the patient; if no ova are found, the drug may be withheld and the idea of ascarides abandoned.

Treatment.—The ascaris is readily expelled by a few grains of santonin. The dose is from $\frac{1}{2}$ to 1 gr. for a child, 3 to 5 gr. for an adult. A good plan of giving the drug is to prescribe three such doses on successive nights, the first and the last dose to be followed by castor oil next morning. Patients, or

mothers, ought to be warned about the peculiar effect santonin has on the urine and sometimes on the vision. I have only once seen any bad effect; in this instance a peculiar sort of intoxication, attended with delirium, which did not quite pass away for several days, followed its exhibition.

Lagochilascaris minor (Leiper, 1909) was removed from an abscess in a native of Trinidad. This species is normally an intestinal parasite, and its occurrence under the skin of man undoubtedly indicates an abnormal infection. *L. major* (Leiper, 1909) is found in the lion and other carnivora. The male is 5 mm. by 2 mm., the female 15 mm. in length. There are three cuticular lips, separated from the body by a cuticular ring. A narrow keel-like edge of cuticle extends along either side of the body. The two spicules are solid chitinous rods. The medial papillæ number over 24 pairs; there are at least 5 pairs of postanal papillæ.

ANKYLOSTOMUM DUODENALE, Dubini, 1843

Synonyms.—*Anchylostomum duodenale; Agchylostoma duodenale; Anchylostoma duodenalis; Strongylus duodenalis; Dochmius duodenalis; Uncinaria duodenalis.*

Ascaris lumbricoides, though an unpleasant parasite, cannot be considered a dangerous one, unless in very exceptional circumstances. It is otherwise with the ankylostomum; this, in many countries, on account of the dangerous cachexia to which it gives rise, called ankylostomiasis, amounts to a positive curse.

Nomenclature.—The form of endemic anæmia with which this parasite is associated is of so marked a character that it has received a variety of distinctive names. Thus, in the French West Indies severe ankylostomiasis is known as *cachexie aqueuse*; sometimes as *malcœur*, or as *mal d'estomac des nègres*; in Colombia it is called *tuntun*, the sufferers being known as *tunientos*; in Brazil it has been called *oppilatio*, *opilaçao*, and *cançaço*; in Europe it is sometimes known as "miner's anæmia," or "tunnel disease," the latter in allusion to the notorious St. Gothard epidemic; the form occurring in Egypt is spoken of as Egyptian chlorosis; in Ceylon it has been

called "beriberi," a name which has not infrequently caused confusion with true beriberi; and, doubtless, elsewhere there are local names for this peculiar verminous anæmia.

Geographical distribution.—Since its discovery by Dubini, in 1838, the ankylostomum has been found so widely diffused that it may be said to occur in all tropical and sub-tropical countries. It occurs in Belgium, and a few years ago was found by Prof. Haldane to be the cause of an epidemic of severe anæmia in a Cornish mine. In northern countries it is rare; but it is abundantly present in the south of Europe, and in the tropical and sub-tropical regions of Asia and America; it has been ascertained to exist in North and South Queensland, Australia, and in several of the islands of the Pacific. So prevalent is it in many parts of India that, according to Dobson, quite 75 per cent. of the inhabitants are affected. In Egypt it is found at nearly every post-mortem examination; and there the anæmia it gives rise to is one of the most common causes for the rejection of recruits for the army. Thornhill regarded its ravages in Ceylon as far more serious than those of cholera; this, not on account of the number of deaths it causes directly, but on account of the vast numbers affected, the chronic nature of the disease, and the aggregate mortality, direct, and especially indirect, for which it is responsible.

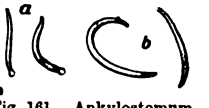


Fig. 161.—Ankylostomum duodenale (natural size). (*Dubini.*)
a, Male; *b*, female.

The parasite (Fig. 161).—The normal habitat of *A. duodenale* is the small intestine of man, particularly the jejunum, less so the duodenum, rarely the ileum or lower reaches of the alimentary canal; very occasionally it is found in the stomach. In these situations it attaches itself by means of its powerful buccal armature to the mucous membrane, from the blood of which it obtains a plentiful supply of nourishment. It is supposed to shift its hold from time to time, the abandoned bite continuing to ooze blood for a short period. It is said to be very prodigal of the blood it imbibes, the red corpuscles passing through its alimentary canal unchanged, the plasma alone being utilized.

The male and female ankylostomes—present generally in the proportion of one of the former to three of the latter—do not differ so much in size as is the case with many of the other nematodes. The male (Fig. 163) measures from 8 to 11 mm. in length by 0·4–0·5 mm. in breadth; the female (Fig. 162) 10–13 mm. in length by 1 mm. in breadth. Both sexes are cylindrical in form, white when they are alive, grey when dead, reddish brown when full of blood. In both sexes the posterior end is the broadest part, whence the body tapers forward to a narrow neck ending in a powerfully armed, bulging and distinct mouth capsule (Fig. 164, B). The margin of this remarkable organ is furnished with four strong, claw-like hooks—two on each side of the ventral line, and two conical teeth—one on each side of the dorsal line. The tail of the female is conical, and ends in a short delicate spine; the anus is subterminal, and the vagina opens on the ventral surface at the beginning of the posterior third of the body. The tail of the male is provided with a large umbrella-like, trilobate bursa (Fig. 164, A) possessing eleven ribs. Two long and very delicate spicules project from the cloaca, which opens at the bottom of the bursa. Owing to the relative positions of the sexual openings, the worms in conjugation look like the Greek γ.

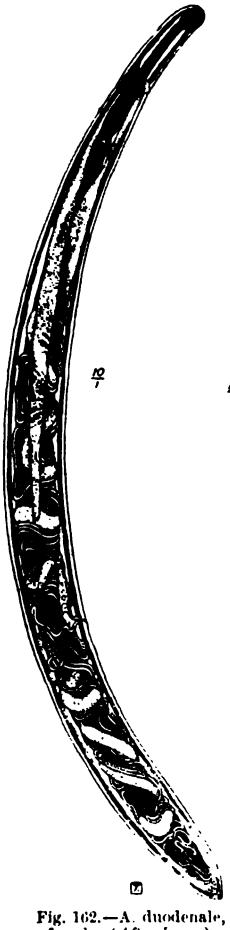


Fig. 162.—A. duodenale, female. (*After Looss.*)

Fig. 163. — A. duodenale, male (*After Looss.*)

Reproduction and mode of infection.—The female ankylostomes produce a prodigious and never-ending stream of eggs (Fig. 157, *b*) which pass out in the fæces. As already stated, while in the body of the host the development of the embryo does not advance very far; but on leaving the human host it proceeds, in suitable circumstances, so rapidly that in one to two days a rhabditiform embryo (0·2 mm. by 0·014 mm.) is born. This minute organism (Fig. 165) is very active, voraciously devouring what organic matter it can find and, for a week, growing rapidly, to 0·56 mm. by 0·024 mm (Fig. 166.) During this time it moults twice. After the second moulting it passes into a torpid condition, in which it ceases to eat, and its growth is suspended. In this state it may live for weeks or months, moving about more or less languidly in muddy water, in mud, or in damp earth. Should chance so determine, it is finally transferred to the human alimentary canal, either in muddy drinking-water, or in the mud or dirt adhering to the hands or the food dishes of the agriculturist, the brick-maker, or other operative engaged in handling the soil; or, it may be, in earth deliberately eaten by the geophagist and children. Arrived in its final host, after moulting again at the end of five weeks (Leichtenstern), it acquires sexual characters and the permanent adult form.

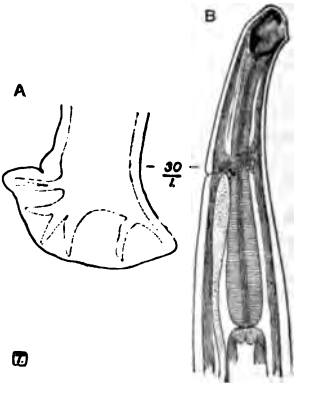


Fig. 164.—A. duodenale. (*After Looss.*) A, Bursa; B, head.

Until recently this was believed to be the only method of infection, but Looss has shown that the parasite may reach the intestinal canal by another route. In making some experiments with

"cultures" of ankylostomum larvæ, Looss inadvertently allowed the culture to come into contact with his hand. This was followed by redness and irritation of the skin of the part and, subsequently,

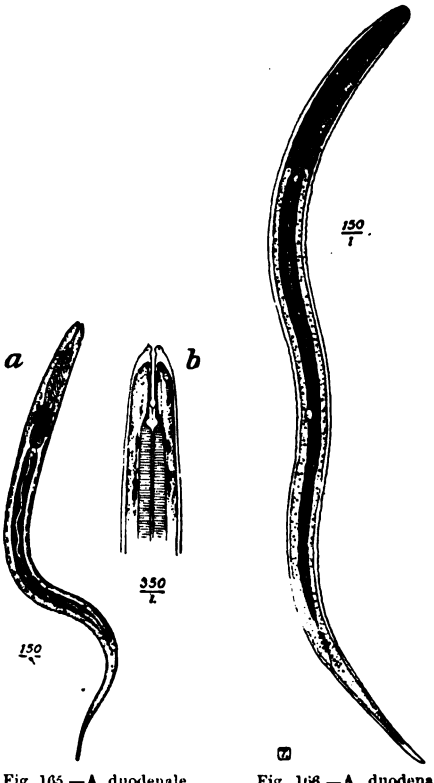


Fig. 165.—A. duodenale. *a*, Young larva; *b*, head. Fig. 166.—A. duodenale, mature larva.
(*Partly after Looss.*)

by well-marked ankylostomiasis; the sequence of events suggesting that the larvæ in the cultures had penetrated the skin of his hand and so attained the bowel. On another occasion Looss repeated this

experiment on a human leg, an hour before its amputation. Sections of the skin showed the larvæ in the hair-follicles, and some had traversed the hair papillæ and lay in the connective tissue around the follicles. Subsequently, other experiments on dogs and men have established the fact that the embryos of *A. duodenale* can enter the skin, and that they do so as a first step towards reaching the intestine. From the subcutaneous tissue they enter the blood-vessels and lymphatics, and by this channel are passively transferred to the lungs. Here they leave the capillaries, enter the air vesicles, and thence along the bronchi and trachea pass into the œsophagus, and so to the stomach. It has been conjectured that during this passage the larva acquires the power of resisting the action of the gastric juice. If this be so, then the indirect route described must be the only way by which the ankylostome can arrive at maturity. The success of feeding experiments, which hitherto has been regarded as proof that the parasite passed directly to the stomach, may be attributed to the passage of the larvæ into the wall of the œsophagus while the dose of larva-laden material was being swallowed.

Sambon has suggested that a proportion of the ankylostomum larvæ pass directly, via the blood-stream, from skin to intestine. To test this suggestion, Fülleborn and Schilling-Torgau in one set of dogs divided the œsophagus, stitching the lower divided end to the skin; in another set of dogs a cannula was inserted into the trachea so that the bronchial secretion could not pass into the œsophagus. The dogs were then infected with *A. caninum*. After a time both sets of dogs gave evidence of small-intestine infections of ankylostomes. Sambon's suggestion, therefore, is to some extent well founded.

The duration of the life of *A. duodenale* in the intestine has not been determined; some state it in months, others in years (Sonsino)—one to three. On account of liability to re-infection, this point, an important one as affecting prognosis, is difficult to determine.

Giles holds that *A. duodenale* may become sexually mature while outside the human body and in the free state; in other words, that it is heterogenetic, an abundant supply of food favouring non-parasitic multiplication. His observations, while supported by Ozzard, Annett, Ross and Sandwith, are opposed by Looss, who points out that probably other free-living nematodes have been mistaken for the species in question; that in fact the illustrations in Giles's report represent three males belonging to different species and characterized by an entirely different configuration of the posterior extremity.

NECATOR AMERICANUS, Stiles, 1902

Synonym.—*Uncinaria americana.*

History.—In May, 1902, Stiles discovered that ankylostomiasis in America was not, as a rule, due to *Ankylostomum duodenale*, but to a new species of the closely allied genus *Necator*, which he named *Necator americanus.*

Geographical distribution.—So far as determined, the distribution of *N. americanus* includes in America—Virginia, North and South Carolina, Georgia, Florida, Alabama, Texas, Porto Rico, Cuba, and Brazil. It has been found by Looss in pygmies from Central Africa, and by others in India (Assam, Burma, Ceylon), West Africa, Rhodesia, Fiji, the Philippines and elsewhere. Probably it is as widely diffused as *A. duodenale*; and in certain localities, Fjii and Ceylon for example, it is the commonest variety of ankylostomum encountered.

The parasite (Figs. 167–9).—*N. americanus* can be readily distinguished from *Ankylostomum duodenale*; it is a shorter and more slender worm. The male measures from 7 to 9 mm. in length by 0·3 to 0·35 mm. in diameter; the female 9 to 11 mm. in length by 0·4 to 0·45 mm. in breadth. The buccal capsule is much smaller, and presents an irregular border; instead of four ventral hook-like teeth, it has a ventral pair of prominent semilunar plates similar to those of the dog hook-worm, *Uncinaria stenocephala;* the pair of dorsal teeth is likewise

represented by a pair of slightly developed chitinous plates of the same nature. The outlet of the dorsal head-gland, usually called dorsal rib or dorsal tooth, projects prominently in the oral cavity. Deep in the

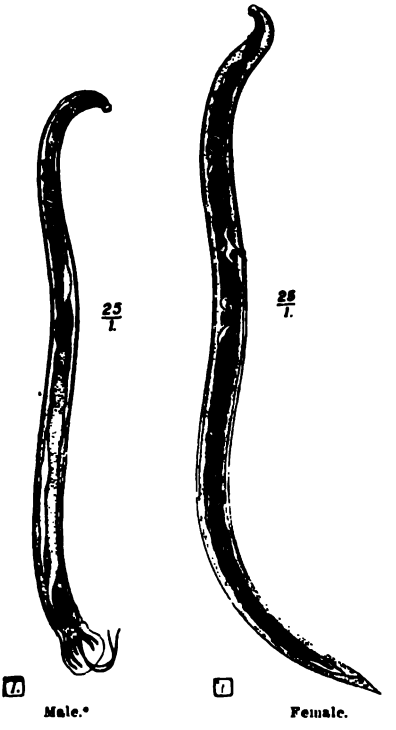


Fig. 167.—Necator americanus. (*After Placencia.*)

buccal capsule are one pair of dorsal and one pair of ventral submedian lancets. The caudal bursa of the male presents a short dorso-median lobe, which often appears as if it were divided into two lobes. The

* Stitt has recently pointed out that there are not really *two separate spicules*, but two united together to form one terminal prong.

dorsal ray is divided to its base, its two branches are prominently divergent, and their tips are bipartite instead of tridigitate, as in *A. duodenale*. The common base of the dorsal and dorso-lateral rays is very short. In the female the vulva is placed slightly in front of the middle of the body. The eggs (Fig. 157, *e*) are larger than in ankylostomum; they measure 64 to 75 μ in length by 36 to 40 μ in breadth.

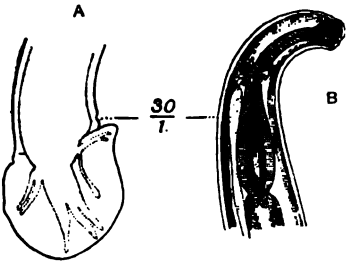


Fig. 168.—Necator americanus. A, Bursa; B, head. (*After Looss.*)

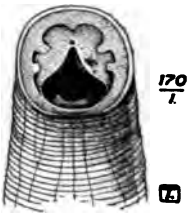


Fig. 169.—Necator americanus, head.

N. americanus inhabits the small intestine of man, and so far has not been found in any other part.

The life history of this worm has not yet been fully investigated; it is probably similar to that of *A. duodenale*.

Ankylostomum braziliense (Looss)

Synonym.—*Ankylostomum ceylonicum* (Lane).

This parasite has been found by Lane in stools of three prisoners in Mymensing Gaol in India. It was thought by Lane to be identical with *A. ceylonicum*, a parasite of the civet cat in Ceylon, but according to Leiper it is identical with *A. braziliense*, a common parasite of dogs and cats in Brazil and China. It has also been found in an African lion born in the Calcutta Zoo. The males are 5 mm., the females 7 mm. long. There are two pairs of ventral marginal teeth. The bursa of the male has clefts dividing the dorsal from the lateral lobes; the dorsal ray bifurcates, each branch bifurcating again. This species is probably of little importance as a parasite of man.

ANKYLOSTOMIASIS

History.—Although Griesinger had previously shown that Egyptian chlorosis was due to the presence of the ankylostomum in the small intestine, and although similar observations had been made on negroes in America, it was not until the very fatal epidemic of anæmia among the miners in the St. Gothard Tunnel (in 1880) had called the attention of European observers to the subject, that the importance of this parasite as a pathogenic agent began to be properly apprehended. Multiplied observations have now shown that, although very minute, these blood-sucking parasites, if present in large numbers and for a length of time, more especially if its victims are poorly fed, are very dangerous ones indeed. The constant drain of blood which their presence entails, the catarrh arising from the irritation caused by the wounds they inflict on the mucous membrane, the consequent impairment of nutrition, and, possibly, the absorption of some hæmolytic toxin—the product of the parasites—give rise to a grave cachexia, disqualifying to a greater or lesser extent the subject of it for work, and, not infrequently, leading to a fatal issue. It is now recognized that many of the cases which were formerly regarded and diagnosed as "tropical anæmia" are cases of ankylostomiasis.

It is not in every instance in which the ankylostomum is present that consequences so serious ensue. There may be dozens of ankylostomes in the intestine without any appreciable anæmia, or, indeed, symptoms of any description whatsoever. Grave symptoms are the exception. One must be careful, therefore, to avoid concluding that the ankylostomum is the cause of every pathological condition with which it may chance to concur.

On the other hand, many inhabitants of tropical and sub-tropical countries are in a state of chronic starvation. Living on coarse, bulky, innutritious food, they are prone to dilatation of the stomach and dyspeptic troubles. In such, any additional cause of

malnutrition, as a swarm of ankylostomes, and a daily though perhaps small loss of blood, may be sufficient to turn the scale against them. In those countries, as elsewhere, there are many who live just on the borderland between health and disease; to such the ankylostomum may prove the last straw that breaks the camel's back.

It may be that in some individuals with special susceptibility, some toxin developed by the parasite, just as in certain cases of *Dibothriocephalus latus* infection, produces a special type of anæmia.

It is evident that as a complication in typhoid, in kidney disease, in dysentery, in malaria, in fact in any chronic or exhausting disease, the importance of this anæmia-producing parasite cannot be ignored.

The practitioner in the tropics, therefore, must be constantly on the look out in all cases of anæmia, of dyspepsia, and of debilitated conditions generally, for the ankylostomum. He must bear in mind that this parasite, as will be presently pointed out, if permitted to remain in the intestine for a length of time, may be the cause, not only of remediable anæmia, but of irremediable anæmia-produced degenerations of various organs. On this account, also, its early recognition becomes a matter of the first importance.

Further, ankylostomiasis is an important disease from the standpoint of the employer of native labour. The invaliding and inefficiency which it causes among coolies, not to mention the deaths, are often financially a serious matter to the planter and the mine-owner. To them, any wisely directed expense or trouble undertaken for the treating and controlling of this helminthiasis will be abundantly repaid by the increased efficiency of the labourer.

Symptoms.—The essential symptoms of ankylostomiasis are those of a progressive anæmia; an anæmia which is generally associated with dyspeptic trouble, but which, in uncomplicated cases, is not associated with wasting. If the progress of a case be unchecked, serous effusions in different organs and fatty degeneration of the heart ensue, and death may occur from syncope or from intercurrent complication.

One of the earliest symptoms of an extensive ankylostomum invasion is pain or uneasiness in the epigastrium. This is generally increased by pressure, but, for the time, may be relieved by food. The appetite, sometimes defective, is more often ravenous, though its gratification is apt to give rise to dyspeptic trouble of various kinds, to colic, to borborygmus, and perhaps to diarrhœa of imperfectly digested food. Constipation may be present in some instances, irregularity of the bowels in others. The taste may be perverted, some patients exhibiting and persistently gratifying an unnatural craving for such things as earth, mud, lime—what is called pica or geophagy. The stools sometimes, though rarely, have a reddish-brown tinge from admixture of half-digested blood. Sometimes they may contain small flakes of blood-tinged mucus. Pure blood is rarely passed; and an extensive hæmorrhage, unless there be concurrent colitis, is still more rare, although, post mortem, considerable quantities of blood may be found in the small intestine. Fever of an irregular, intermitting, or even of a subcontinued type is common. On the other hand, the temperature may be constantly subnormal. Or these conditions may alternate. After a longer or shorter time, symptoms of profound anæmia gradually disclose themselves. The mucous surfaces and the skin become pallid, the face is puffy, and the feet and ankles are swollen. All the subjective symptoms of a definite anæmia now become more and more apparent; there are lassitude, breathlessness, palpitations, tinnitus, vertigo, dimness of sight, mental apathy and depression, liability to syncope, etc. The circulation is irritable, and hæmic bruits can be heard over the heart and larger blood-vessels. Ophthalmoscopical examination may reveal retinal hæmorrhages.

From some of these symptoms, were it not that with the advancing anæmia there is no loss of weight, one might be led to suspect the possibility of tuberculous or cancerous disease, or of Bright's disease. So far from losing weight, the patient may appear quite plump and, though hæmocytometric estimates testify to a slow and steady fall in the corpuscular richness of

the blood until the lowest limit compatible with life is reached, there is no true poikilocytosis as in idiopathic pernicious anæmia, no excessive leucocytosis as in leucocythæmia, and not necessarily any enlargement of lymphatic glands, liver, or spleen. There is generally a marked eosinophilia. The depression in the hæmoglobin value of the corpuscles is considerably greater than the fall in their numbers.

The rate of progress is very different in different cases. In some a high degree of anæmia may be attained, and even a fatal issue ensue within a few weeks or months of the appearance of the first symptoms. Such rapid cases are rare; more frequently the disease is an exceedingly chronic one, ebbing and flowing or slowly progressing through a long series of years.

Should serious ankylostomiasis occur before puberty, the growth and development are apt to be delayed and stunted.

Diagnosis.—Provided its presence be suspected, ankylostomiasis is easily diagnosed. In tropical countries, in patients coming from tropical countries, and in miners who work in very warm mines in cooler climates, anæmia with concurrent eosinophilia should always suggest a microscopical examination of the fæces. If the ova (Fig. 157, *b*, *e*) of *A. duodenale* or of *N. americanus* are discovered,* and no other reason for the anæmia be made out, the presumption is that one of these parasites is at the root of the mischief; at all events, no harm is

* Bass considers that by the usual microscopical examination of fæces quite 20 per cent. of infections with *A. duodenale* are missed; he recommends examination of fæces as follows: "A quantity of fæces is well diluted with water, 1 to 10, and strained through gauze to get rid of coarse particles. It is then centrifuged and the fluid poured off, the centrifuge tube being refilled and centrifuged again until all the diluted fæces have been used. The precipitate is rewashed several times with water as long as anything can be washed out. Calcium chloride solution of a specific gravity of 1050 is now added and the precipitate washed as before. This salt is preferable to others because of its hygroscopic properties, and its addition to the fæces disposes of everything having a specific gravity below 1050. The precipitate is now examined, and will be found to contain most of the eggs which were present in the whole amount of original fæces."

likely to result from treatment based on this supposition. On the other hand, if no ova are found it must not be concluded that the case is not one of ankylostomiasis; for it sometimes happens that, in the later stages of the disease, symptoms will persist although the parasites which caused them in the first instance have disappeared spontaneously, or have been got rid of by treatment. Permanent degeneration of the alimentary canal, of the heart, liver, kidneys, and blood-forming organs, may remain, and even prove fatal, although the primary cause is no longer present. The history and the absence of other sources of anæmia are all we may have to go upon in such circumstances.

Ankylostomiasis is sometimes confounded with beriberi, and vice versa. The presence of paretic and cardiac symptoms not accounted for by the moderate degree of anæmia in beriberi, and their absence in ankylostomiasis, suffice for diagnosis. The anæmia of ankylostomiasis differs from that of malaria, inasmuch as the latter is accompanied by enlargement of the spleen, a sallow and perhaps pigmented complexion, an icteric tint of the scleræ, occasional attacks of well-marked periodic fever controlled by quinine, and, especially, the presence at such times of the malaria parasite in the blood. As an additional diagnostic feature, Rogers has pointed out that whereas in malaria the loss of hæmoglobin is in proportion to the loss of red blood-corpuscles, in ankylostomiasis it is in excess of this. Of course, ankylostomiasis and malarial cachexia may concur, and often do concur, in the same individual.

Some idea of the intensity of the affection may be got from an enumeration of the eggs in a given quantity of fæces; according to Grassi and Parona, the presence of 150 to 180 eggs per c.cg. indicates an infection of about a thousand worms, male and female.

Pathological anatomy and pathology.—As already mentioned, the bodies of the victims of ankylostomiasis are not wasted; on the contrary, there is plenty of fat in the usual situations. The appearance of plumpness is further increased by a greater

or lesser amount of general œdema. There may be effusions in one or more of the serous cavities. All the organs are anæmic. The heart is dilated and flabby, its muscular tissue being in a state of pronounced fatty degeneration. The liver, also, is fatty, and so are the kidneys.

If the post-mortem examination be made within an hour or two of death, the ankylostomes, in numbers ranging from a few dozens up to many hundreds, will be found still attached by their mouths to the mucous surfaces of the lower part of the duodenum, of the jejunum, and, perhaps, of the upper part of the ileum; but if the examination has been delayed for some hours, the parasites will have dropped their hold, and are then to be found lying in the mucus coating the inner surface of the bowel. Many small extravasations of blood —some fresh, others of long standing—are seen in the mucous membrane, a minute wound in the centre of each extravasation representing the point at which the parasite had been attached. Sometimes blood-filled cavities, as large as filberts, are found in the mucosa; each cavity enclosing one or two worms and, probably, communicating by means of a small hole with the interior of the intestine. Old extravasations are indicated by punctiform pigmentations. There may be evidence, in the shape of vesiculations and thickening of the mucosa, of a greater or lesser degree of catarrh. Occasionally, streaks or large clots of blood are found in the lumen of the bowel.

Daniels and others report that microscopical examination of the liver and kidneys shows the presence, within the cells of the parenchyma, of grains of yellow pigment having the reactions of hæmatoidin; indicating an intravascular blood destruction such as occurs in pernicious anæmia and other diseases in which excessive hæmolysis is a feature. On this account, and also because he finds granules of a ferrous nature in the liver cells, Daniels concludes that the anæmia in ankylostomiasis is, in a measure, the result of blood destruction within the vessels by some toxic substance produced by the parasite and absorbed

from the bowel. These results have not been confirmed by all other observers; on the contrary, the late Dr. Beaven Rake concluded, from careful estimates of the amount of iron in the livers of five cases of ankylostomiasis, that in this disease the hepatic iron is below the normal average, and that the anæmia is entirely owing to the direct abstraction of blood by the parasites. Further observations are necessary before this question can be decided.

Treatment. *Male fern.*—Until the introduction of thymol by Bozzolo in 1880, extract of male fern was the anthelmintic usually employed in ankylostomiasis.

Thymol.—Before the administration of thymol the patient should be put on liquid diet for a day or two, and have the bowels well cleared out by an aperient. In the morning, and following the action of the aperient, three or four 10- to 30-gr. doses of well-triturated thymol, in cachets, in capsules, or in emulsion, are given on an empty stomach at intervals of an hour. If the bowels do not open spontaneously within four or five hours of the last dose an aperient should be given. Usually, by this treatment many ankylostomes are expelled and may be found in the motions. One such course of thymol may suffice; but it is well, after a week has elapsed, again to examine the stools microscopically, and, if it be found that ova are still being passed, to repeat the course of thymol once or oftener.

Certain precautions have to be observed in employing this drug. At times it gives rise to a very unpleasant form of intoxication—vertigo, excitement, etc., and the urine may become dark, as in carbolic-acid poisoning. It is advisable therefore for the patient, while taking the drug, to keep his bed and to lie down for several hours after the last dose. Thymol is very insoluble in water, and is consequently, in ordinary circumstances, not readily absorbed in poisonous quantities; should, however, the patient, while thymol is present in the stomach, partake of any alcoholic drink, there is considerable risk of poisoning ensuing. Alcohol, ether, glycerine, turpentine, chloroform, and

oils are all solvents of thymol, and must therefore be avoided when this drug is being exhibited. Thornhill related an instance in which a fatal result was brought about, apparently, by neglect of the obvious precautions suggested by these facts. A man had received 30 gr. of thymol in water at 7 a.m. "He experienced no special symptoms after it, and at 9 a.m. the nurse gave him a second dose of 30 gr. As this man was supplied with arrack as an extra, and as in such cases a portion of the arrack was usually given at 9 a.m., the nurse gave it to him just after administering the second dose of thymol. The result was that intense collapse set in almost at once, and, notwithstanding all efforts, the man died within twenty-four hours, the collapse manifestly being due to the arrack dissolving the thymol, which was thus absorbed." Thornhill mentions two additional fatal cases of thymol poisoning occurring in his experience; other writers have recorded similar fatalities. For this reason, and because it is an extremely unpleasant drug to take—sometimes giving rise to severe burning sensations in the stomach, throat and gullet, and, not infrequently, to excitement, giddiness, fainting, and vomiting—an equally efficient but safer drug is a desideratum.

Without careful preparation by rest and judicious feeding, thymol must on no account be used in advanced cases of ankylostomiasis or where prostration is extreme. It is contra-indicated in gastritis, dysentery, nephritis, and in active heart disease.

Beta-naphthol given in the same way as thymol, in doses of 15 gr. repeated every two hours for two or three times, is just as efficacious, is cheaper, and much less unpleasant, and is therefore to be preferred.

Oil of eucalyptus 30 minims, chloroform 45 minims, castor oil 10 drachms, one half first thing in the morning, the other half thirty minutes later, is a very efficient vermifuge in ankylostomiasis, much less unpleasant and much less dangerous than any of the foregoing. It can be repeated for several days in succession. I have used this combination

several times in Europeans who had on previous occasions taken thymol; they preferred the eucalyptus mixture.

Convalescence.—The dieting of convalescents from serious ankylostomum disease must, for a time, be very carefully conducted. In such, a rich, full dietary is to be avoided until the powers of digestion have become re-established; otherwise, enteritis and diarrhœa may prove very troublesome and retard recovery —perhaps prevent it altogether. Iron and arsenic are indicated as blood restorers.

Prophylaxis.—In devising a system of prophylaxis for ankylostomiasis, the fact that it is by means of the fæces of the already infected that the parasite is spread must be kept prominently in view. Fæcal contamination of the soil and water must therefore be prevented. The promiscuous deposition of fæces about huts, villages, and fields must be interdicted. Abundant and easily accessible privy accommodation must be provided in coolie lines, in miners' camps, in native villages, and along the highways of traffic. In the absence of a more elaborate system of conservancy, pits or trenches will suffice. They may be filled up with earth and fresh ones opened from time to time. I believe the Chinese plan of storing night-soil for months in large, cemented, watertight pits is a good one. It is known that if the ova of the ankylostomum are kept in pure fæces the embryo is developed and escapes from the egg in due course; but it is also known that, unless the embryo be supplied with a certain amount of air and earth, it soon dies. The thing to be avoided, therefore, is the mixing of *fresh* fæces with earth. By the Chinese system the embryos of the ankylostomum are killed, and, at the same time, a valuable fertilizer is secured for the agriculturist.

It is manifest that in devising privies and sanitary regulations the habits of the people they are intended to benefit must be taken into account; if this be not attended to, if native habits and prejudices are ignored, any system, no matter how perfect it may be in theory, will fail in practice.

The water supply should also be carefully guarded from all possible sources of fæcal contamination. Drinking-water, unless above suspicion, should be boiled or strained. So far as possible, facilities for removing all earth and mud from the hands and dishes before food is partaken of should also be provided and their use encouraged.

Badly contaminated ground had better be abandoned. If this should be found impracticable, the soil should be turned over with the plough, or roasted with grass fires, or treated in such a manner that any ova or embryos it may contain are destroyed or buried. The systematic periodical inspection of plantation coolies is to be recommended. At these inspections all subjects of anæmia or dyspepsia should be put aside for more careful examination; if the ova of ankylostomes are found in their fæces a judicious dosing with some of the drugs mentioned may avert serious disease in the individual, and also prevent him from becoming a source of danger to his companions.

In view of the great danger to health that exists in certain countries from this and similar parasites, the sanitary authorities in such places ought to circulate among the people, by means of printed leaflets or posters, a few simple directions for the prevention of ankylostomiasis and kindred diseases.

Recently attempts have been made in Porto Rico and elsewhere to reduce or exterminate the prevailing ankylostomiasis. Special officers have been detailed for the purpose, whose duty it is to submit the entire population to systematic drugging with β-naphthol. The result in the improvement of the general health and increase in the aggregate labour capacity has been most encouraging. This is an example of sanitary energy which we might follow with advantage in our own tropical possessions.*

* An anti-hookworm—as the ankylostome is called in America—campaign is now being waged in the United States, financed by Mr. Rockefeller. State and county dispensaries for free examination and treatment of applicants have been established. The total number treated in 11 States in 1912 was 238,755; a Commission has been working for three years, and has treated 393,556 people at a cost of a little over a dollar per head.

ANKYLOSTOMUM DERMATITIS

A form of dermatitis affecting the feet of coolies on plantations in Assam, in the West Indies, and probably elsewhere in the tropics, and variously known as ground itch, pani-ghao, water itch, water pox, water sores, sore feet of coolies, has been ascribed by Bentley to the penetration of the skin by ankylostomum larvæ. This disease is of much economic importance to the planter.

The soil in the neighbourhood of coolie lines is extensively contaminated by fæcal matter. During rainy weather the ankylostomum ova in the fæcal materials are hatched, and the larvæ escape into, and possibly multiply in, the damp earth. The bare feet of the coolies are constantly soiled with this larva-laden earth, and in this way, in many tropical plantations, Looss's experiment is unintentionally carried out on a large scale. Dermatitis, vesiculation, and it may be pustulation or even extensive ulceration, and probably ankylostomiasis anæmia ensue. The services of the affected coolie are lost to the planter till the irritation or ulceration subsides and the anæmia is cured.

Bentley's suggestion has been contradicted by Dalgetty, Stiles and others. Looss also points out that the symptoms of ground itch do not tally with those caused by the penetration of ankylostomum larvæ through the skin. Perhaps coolie itch may not in every instance be produced in this way, but undoubtedly it is so in a proportion of cases. A patient of mine, a sugar planter, who at that time knew nothing about the ankylostomum, observed that an attack of coolie itch in any of his labourers was sure to be followed by anæmia. He assumed that the skin trouble was the cause of the anæmia, and that the former was produced by a micro-organism picked up from the soil. He made his coolies, on going out to their work in the morning, walk through a bucket of Barbados tar, and then through a heap of sand, with the result that coolie itch and anæmia ceased on his estate.

Personal cleanliness and the use of some form of foot covering during the wet season, together with the prophylactic measures for ankylostomiasis already mentioned, are the special preventive means indicated as against this disease. As regards treatment, antiseptic foot baths and some soothing ointment are indicated.

ŒSOPHAGOSTOMUM, APIOSTOMUM, Willach, 1891

Synonym.—*Œ. brumpti*, Railliet and Henry, 1905.

History.—The occurrence in man of this parasitic nematode was discovered by Brumpt, in 1902, at the post-mortem of a thirty-year old Pouma negro on the river Omo, Africa. Six immature females were found within cyst-like nodules in the wall of the cæcum and colon. Subsequently the same parasite was found by Leiper in natives from Northern Nigeria. Johnson found that 4 per cent. of the prisoners in Zungeru gaol were infected with the same helminth. We know already of a number of species of the same genus occurring in the Quadrumana. *Œ. apiostomum* has been found in the gorilla, in the ourang-outang, in the chimpanzee, and in various monkeys belonging to the genera *Cercopithecus*, *Cynocephalus*, and *Macacus*; in these, if the infection is severe, it gives rise to dysenteric symptoms.

The parasite.—The young females found by Brumpt varied in length from 8·5 to 10·2 mm. and presented a maximum breadth of 295 to 325 μ. The cuticle is transversely striated; the anterior extremity exhibits the ovoid cuticular expansion characteristic of the genus, limited anteriorly by a salient oral ring (oral vestibule) and posteriorly by a constriction which is especially marked on the ventral surface and 200 μ distant from the oral vestibule. The posterior extremity of the female worm tapers gradually to a caudal point slightly bent dorsally. The male has a terminal bursa similar to that of the *Ankylostomum duodenale*, but differs in that the trunk of the dorsal ray bifurcates some distance from the bursal edge into two branches forming a horseshoe-shaped structure, each limb of which gives off a short lateral horn near its base. The oral vestibule is provided with a crown of twelve sharp chitinous plates directed forwards and inwards, and bears six papillæ, two lateral and four submedian. The œsophagus is club-shaped and measures 470–500 μ in length by 150 μ in its widest diameter. Anteriorly, it

opens into the oral capsule with three slightly recurved teeth about 8 μ long, which fit into three corresponding indentures of the posterior border of the oral capsule. Posteriorly, it presents a three-lobed valve. The intestine runs almost in a straight line to the anus, which opens at 170–200 μ from the posterior extremity. The vulva is placed anteriorly to the anus at 350–475 μ from the caudal end. Neither anus nor vulva is marked by any prominence of the body wall.

The ova of *Œ. apiostomum*, like those of other parasites belonging to this genus or to the closely allied genus *Sclerostoma*, probably hatch in water, and by this medium reach a fresh host, penetrating either through the œsophagus or the skin. They finally settle beneath the intestinal mucosa, usually between the ileo-cæcal valve and the anus, and here grow considerably in size, feeding on the blood of the host. Having practically reached the adult stage, they leave their cysts for the purpose of copulation and oviposition, and they and their eggs are expelled with the fæces.

Life history and pathogenesis.—The allied species, *Œ. columbianum*, which, according to Curtice, is frequent in adult sheep in the south of the United States and is more particularly observed in the autumn and winter, does not appear to cause any serious trouble except when present in great numbers. The parasite may be found in its adult state within the lumen of the cæcum or colon, but it is found more frequently in the larval stage lodged beneath the mucous membrane in cysts varying in size from that of a pin's head to that of a hazel-nut, each cyst containing a coiled-up worm. The species peculiar to apes and monkeys are likewise found during their larval stage within small hæmorrhagic cysts beneath the mucosa of the cæcum and large intestine. The parasites are blood-suckers; their intestines are crammed with erythrocytes. The larger cysts usually present a small perforation at their summit; through this the worm protrudes and escapes. *Œ. dentatum*, which inhabits the pig, the wild boar, and the white-lipped peccary (*Dicotyles labiatus*), is found not only in the cæcum and colon, but also farther up in the small intestine, and von Linstow found it within the liver. According to Railliet, the eggs of this species hatch in water within three or four days, the liberated embryo measuring 200–250 μ.

TRIODONTOPHORUS DEMINUTUS, Railliet and Henry, 1905

This sclerostome (Fig. 170) is an intestinal parasite of monkeys inhabiting the large intestine. It has several times been found in natives, post mortem, by Turner in the Transvaal and by Stannus in Nyasaland. The worms are about the size and shape of a female ankylostome. The male is 9·5 mm. long and 0·56 mm. broad; the female, with a tapering posterior extremity, 14–16 mm. in length and 0·73 mm. broad.

The male has a terminal bursa provided with a posterior ray split into two widely arching component parts, vaguely recalling the arrangement in œsophagostomum. The genital orifice of the female opens posteriorly. The vagina is short and opens into two uterine tubes. The mouth collar is moderately developed, and the entrance to the mouth is surrounded by a double series of delicate fringes composed of cuticle—the corona radiata. The buccal capsule is a barrel-shaped chitinous

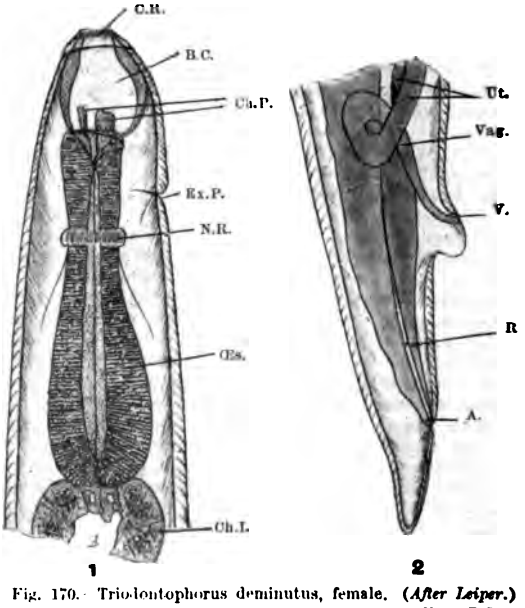


Fig. 170.—Triodontophorus deminutus, female. (*After Leiper.*)

1, Anterior extremity; 2, posterior extremity. C.R., corona radiata; B.C., buccal cavity; Ch.P., chitinous plates; N., nerve ring; Œs., œsophagus; Ch.I., chyle intest.; Ut., uterus; Vag., vagina; V., vaginal opening; R., rectum A., anus.

structure; posteriorly it comes into contact with the œsophagus. The œsophagus is stout and muscular and triradiate on section. Each of the surfaces of the œsophagus terminates in a chitinous plate projecting into the buccal capsule. The cuticle is transversely striated.

PHYSALOPTERA MORDENS, Leiper, 1907

This appears to be a common human intestinal parasite in Central Africa. Leiper found it frequently amongst material sent by Dr. Turner of Johannesburg. Owing to its resemblance

to *Ascaris lumbricoides* it has been taken for miniature specimens of that species. The males are 50 mm., the females 55 mm. in length, and 2–3 mm. in breadth. The posterior end tapers rapidly in the female, terminating in a sharp point. The mouth has a cuticular cuff and two lips provided with papillæ and teeth. The bursa is bladder-shaped with pedunculated external papillæ and unequal spicules. The female has two ovaries and vulva situated anteriorly.

SYNGAMUS KINGI, Leiper, 1913

Dr. King, of St. Lucia, forwarded some specimens of this parasite in copula to Leiper; they are said to have been coughed up by a woman.

Copulation is permanent, males and females being found adherent to one another. The male has two equal spicules and the caudal bursa is provided with many ribs; the mouth is large and terminal, leading into a dilated buccal capsule, at the bottom of which there are six sharp teeth.

Leiper was first of opinion that the parasite was merely *S. trachealis* of poultry, and an accidental occurrence in man. Further examination has convinced him that it is probably a new species more nearly related to the members of the genus found in mammals, but more especially to *S. dispar* of the puma (*Felis concolor*).

STRONGYLOIDES STERCORALIS (Bavay, 1876)

Synonyms.—*Anguillula stercoralis; A. intestinalis; Leptodera stercoralis; L. intestinalis; Rhabdonema intestinale.*

It sometimes happens that while searching the fæces for the ova of the ankylostomum, the observer is astonished by seeing a small, snake-like animal (Fig. 171) suddenly rush across the field of the microscope. On careful examination, this animal is found to be about 0·2 mm. or 0·3 mm. in length by 0·013 mm. in breadth; to have a sharply pointed tail and a rounded head; to be transparent; and to exhibit a short œsophagus which terminates in a double œsophageal bulb, the posterior end of which is provided with three tooth-like segments. This is the larval form of *Strongyloides stercoralis.*

Strongyloides stercoralis was discovered by Normand in 1876. For a time it was supposed to be a cause of a form of chronic diarrhœa very prevalent in Cochin China. Later investigations, while clearing up the natural history of the parasite, have robbed it of any claim to pathological importance. It has been found that, though not so common, its geographical distribution is about coextensive with that of *Ankylostomum duodenale*, and that the physical conditions demanded for the non-parasitic stages of these two worms are about the same. Powell found it in India in about 15 out of every 20 cases [illegible] anæmia.

The mature strongyloides (Fig. 172) is a minute, slender worm, measuring 2–3 mm. in length by 0·06 mm. in breadth. No male parasite has been discovered. The adult female is readily recognized by her dimensions, and by the string of five or six ellipsoidal eggs (0·01 mm. by 0·034 mm.) visible about the centre of the body.

As Kanazy has shown, the parasite bores deeply into the mucous membrane of the intestine, and frequently into the epithelium of Lieberkühn's glands, both for nourishment and oviposition. The eggs develop in the intestinal wall, so that

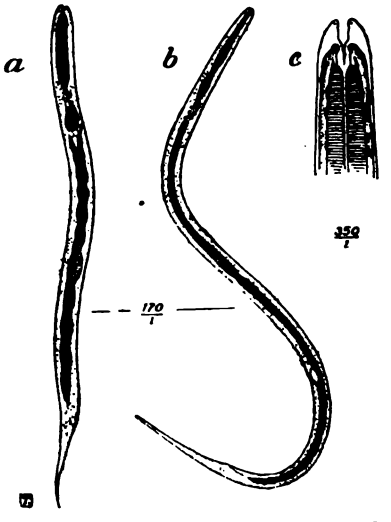


Fig. 171.—Strongyloides stercoralis. (*Partly after Looss.*)
a, Young larva from fæces; *b*, mature larva; *c*, head.

before leaving the host, unless during violent purgation, the larva has escaped and is swimming about in the fæces, as already described, with great vigour, especially when these are fluid. Only in the event of violent purging do the ova appear in the stools. Such ova (Fig. 157, *d*) are readily recognized by the way in which they are strung together, end to end, inside a delicate tube. On leaving the host, unless they have access to some non-putrefying fluid, the larvæ soon die; it is necessary, therefore, if we would follow their further development, to mix the fæces with water. If this mixture be kept at a low temperature the young rhabditiform larva develops into a filariform larva which, on reaching its host, assumes the mature parasitic form already alluded to. If, on the

contrary, the cultivating medium be kept at a higher temperature, the larvæ develop into male (0·7 mm.) and female (1·0 mm.) rhabditic forms which, in time, produce in their turn filariform larvæ, similar to those obtained directly from the embryo in cold climates, and capable, on being swallowed by man, of developing into mature *Strongyloides stercoralis.*

This parasite must undoubtedly produce considerable irritation of the bowel, but its pathogenic rôle has not been definitely ascertained. It is usually present in large numbers, and has been found occasionally coiled up in the intestinal follicles

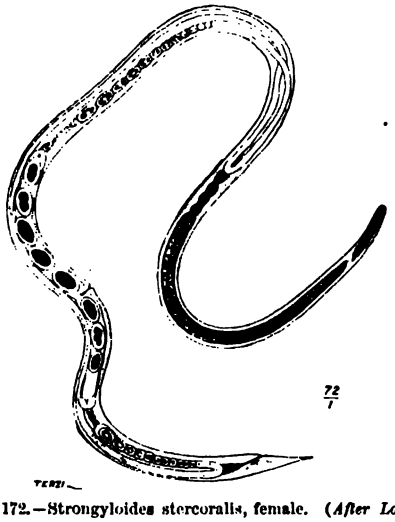


Fig. 172.—Strongyloides stercoralis, female. (*After Looss.*)

The larvæ may pierce into the lacteals, and have been found in the blood. Van Durme has shown that, like the larvæ of *Ankylostomum duodenale*, the filariform larvæ of strongyloides may penetrate through the skin.* Hitherto the use of anthelmintics has not proved effectual in procuring their expulsion. Sonsino recommends the prolonged exhibition of liquor ferri perchloridi in combination with small doses of thymol.

The prophylaxis for strongyloides is the same as that recommended for *Ankylostomum duodenale.*

* These experiments have recently been confirmed by Fülleborn, who found larvæ in the tracheal sp[illegible] tracheotomized and artificially infected dog.

STRONGYLUS SUBTILIS (Looss, 1895)

Synonym.—*Trichostrongylus instabilis* (Railliet, 1893).

Looss has described a very delicate nematode (Figs. 173–5) frequently encountered in Egyptian fellahs, and since found by

Fig. 173.—Strongylus subtilis, male.

Ijima in Japan. Its habitat is the upper part of the small intestine. The male, which is provided with two spicules, is from 4 to 5 mm. in length by 0·07 mm. in breadth; the female

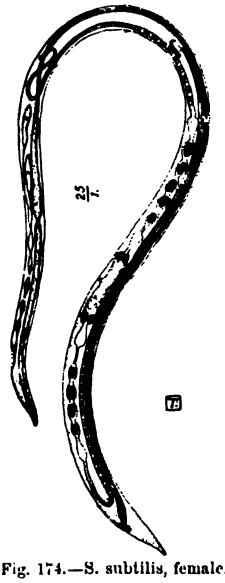


Fig. 174.—S. subtilis, female.

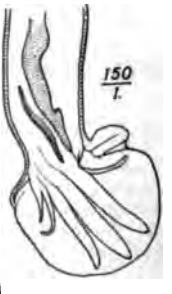


Fig. 175.—S. subtilis, bursa. (*After Looss.*)

is slightly larger and is much more abundant than the male. The eggs (Fig. 157, *a*) are oval, thin-shelled, with an unseg-

mented vitellus, and measure 63 μ by 41 μ. This parasite does not occur in large numbers; and, as its mouth is unarmed and its dimensions are exceedingly minute, it does not appear calculated to give rise to any particular symptoms.

GNATHOSTOMUM SPINIGERUM (Owen, 1838)

Synonyms. — *Cheiracanthus siamensis*; *Strongylus siamense* (Levinsen, 1839).

History.—*Gnathostomum spinigerum* was discovered by Deuntzer in Bangkok (Siam) and described by Levinsen, who proposed to call it *Cheiracanthus siamensis*.

Geographical distribution.—So far it has been seen in Siam only. It was met with in three patients, one of whom had five or six of these worms.

The parasite.—Only one female specimen was preserved and forwarded to Levinsen (Fig. 176). It measured 9 mm. in length by 1 mm. in breadth. The cephalic extremity, slightly narrower than the rest of the body, had the appearance of a sucker bordered by two lips and was surrounded by eight rows of hooklets. The posterior extremity terminated in a three-lobed prominence, at the base of which the anus opens. The anterior third of the body was beset with tridentate spines, followed by scattered simple spines, which gradually became smaller and then disappeared entirely. The vulva opened a little behind the middle of the body. Subsequently, Leiper described the male—it measured 10·5 mm. by 0·6 mm. It had two large fleshy lips; two unequal spicules; two preanal and two postanal papillæ. Leiper considers its normal host in Siam to be the cat.

Fig. 176.—Gnathostomum spinigerum. (*After Levinsen.*)

Life history and pathogenesis.—We know nothing of the life history of *Gnathostomum spinigerum*. Other species of the genus live in the stomach of various vertebrates. Before attaining maturity they are found in cysts beneath the mucosa. *G. spinigerum* is found in various kinds of wild cats (*Felis catus*, *F. concolor*, *F. tigris*). Lewis found it in the pariah dogs of Calcutta. *G. hispidum* lives in the stomach of hogs. Fedschenko found it in a Turkestan wild hog and in a Hungarian domestic hog. Csokor found it in hogs slaughtered at Vienna, Strose in Bakony's hogs, and Collin in cattle in Germany. In Vienna butchers have long known this parasite under the name of "three-coloured worm." The parasite described by Levinsen came from a young Siamese woman, who presented a livid and painful tumefaction of the breast with slight fever. Rounded nodules the size of beans appeared at the seat of inflammation, beneath the skin. From one of these nodules the gnathostomum protruded.

2. TREMATODES

WATSONIUS WATSONI (Conyngham, 1904; Stiles and Goldberger, 1910)

Synonyms.—*Amphistomum watsoni; Cladorchis watsoni; Paramphistomum watsoni.*

History.—This parasite was found in 1904 by Watson in the duodenum and upper part of the jejunum of a negro patient from German West Africa who died of starvation and diarrhœa. The stools were numerous, watery, and of a bilious colour, and contained many yellow, translucent, oval trematodes. At the post-mortem the jejunum was found to be full of these trematodes, some of them alive and still adherent. The mucosa showed no hæmorrhages, but appeared to be slightly congested. The other parts of the bowel, as also the other organs, were normal. The parasite is said to occur in monkeys and to be common in natives near Lake Tchad.

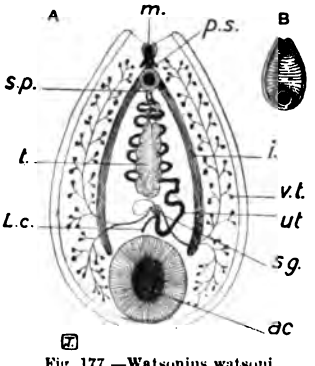


Fig. 177.—Watsonius watsoni. (*After Shipley.*)

A, Magnified; B, natural size.

The parasite.—*W. watsoni* (Fig. 177) is of a reddish-brown colour and measures 8 to 10 mm. in length by 4 to 5 mm. in breadth; it is oval in shape. The oral sucker is small; the ventral sucker or acetabulum large and at the posterior extremity of the body. The genital pore opens at the anterior end of the ventral surface on a level with the bifurcation of the intestine. The ova measure 125 μ in length by 75 μ in breadth.

Life history.—We know nothing of the life history of this parasite, but probably it is similar to that of *P. cervi*, the conical fluke of cattle and sheep, which was thoroughly worked out by Looss in 1896. The eggs of *P. cervi* contain a ciliated embryo (miracidium) which escapes from the eggshell under the stimulus of light and moisture. Swimming about in the water, which it must necessarily reach for further

development, it penetrates into the visceral cavity of certain snails (*Physa alexandrina*, *P. micropleura*), and in these develops and multiplies parthenogenically. In about two months, having attained the so-called cercaria stage, its progeny escape from the snail, swim around in the water, and finally encyst themselves on plants or other objects. The final host (cattle, sheep, etc.) is attained either through drinking-water or pasture.

Geographical distribution.—Information is as yet very scanty, but there is reason to believe that *W. watsoni* is by no means uncommon in certain parts of Northern Nigeria, where it gives rise to serious intestinal trouble, especially in children. A patient who had lived there for some time told me that on one occasion, being seized with violent diarrhœa, he passed about a pint of material containing innumerable moving bodies which he described as resembling the heads of tadpoles, doubtless specimens of *W. watsoni*.

Treatment.—As for adult tapeworms.

GASTRODISCOIDES HOMINIS (Leiper, 1913)

Synonyms.—*Amphistomum hominis; Gastrodiscus hominis* (Lewis and McConnell, 1876).

History.—This parasite was described by Lewis and McConnell in 1876 from two sets of specimens, the first procured from O'Brien and Curran, who found them in the vicinity of the ileo-colic valve at the post-mortem of an Assamese in Gowhatty; the second belonging to the Pathological Museum of the Calcutta Medical College, and presented in 1857 by Simpson, who found them in the cæcum and ascending colon of an Indian who died from cholera in the Tirhoot gaol hospital. *G. hominis* is now found to be a much more common parasite of man than was formerly supposed. A study of serial sections has convinced Leiper of the necessity of removing it from the genus *Gastrodiscus* on the following grounds: (1) the presence of a large imminent genital papilla in place of the genital atrium of gastrodiscus; (2) testes tandem; (3) genital orifice on the neck, not on

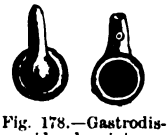


Fig. 178.—Gastrodiscoides hominis. (Nat. size.)

the ventral surface; (4) ventral aspect of the disc smooth and quite free from sucker-bearing papillæ.

Geographical distribution.—We know little of the geographical distribution of *G. hominis*; it is probably widely distributed throughout Asia, and appears to be rather common in India. Law and Wise found it in East Indian immigrants in British Guiana, Mackie in seven patients in Assam, by one of whom two hundred worms were passed after treatment with thymol. The pig, apparently, is its normal host (Mathis and Leger).

The parasite (Fig. 178) is of a reddish colour in fresh specimens, and measures 5 to 8 mm. in length by 3 to 4 mm. in breadth. Its body is divided into an anterior rather slender conical portion, and a posterior flattened ventrally concave disc; the oral sucker is small, ventral; the acetabulum is at the posterior border of the ventral disc. The genital pore opens at about the middle of the anterior portion on a level with the bifurcation of the intestine. The testicles are two in number and lobate; the vas deferens is very sinuous. The eggs are oval and measure 150 μ by 72 μ, and are operculated. The life history is probably as in *Paramphistomum cervi*.

Pathogenesis.—*G. hominis* is found in the cæcum and colon. The mucous membrane is marked with numerous red spots resembling leech bites. These spots are caused by the parasites, which, attaching themselves to the mucosa by means of their suckers, produce minute pimple-like elevations of the surface. When the parasites occur in great numbers they cause much irritation.

Treatment.—The same as for adult tapeworms and ankylostomes—thymol.

FASCIOLOPSIS BUSKI (Lankester, 1857)

Synonyms.—*Distoma buski*; *Dicrocœlium buski*; *D. rathouisi*.

History.—*Fasciolopsis buski* was first described by Busk in his "Diseases of the Liver," published in London in 1845. Busk found this parasite in 1843 in the duodenum of a Lascar who died at the Seamen's Hospital. The pig is the normal host.

Geographical distribution.—*F. buski* is an Asiatic trematode; it has been found in India, Assam, the Straits Settlements, Sumatra, and China.

The parasite (Fig. 179) is the largest trematode inhabiting man. It measures 24 to 40 mm. or more (75 mm. according to Busk) in length by 12 to 14 mm. in breadth. In shape it is an elongated oval, rather narrower anteriorly than posteriorly, with flat ventral surface, slightly convex dorsal surface, and very thin margins. It has a smooth skin without spines. The oral sucker (0·5 mm. in diameter) is subterminal and placed on the ventral surface. The ventral sucker is larger (1·6 to 2 mm. in diameter) and placed close to the oral. It is prolonged into a kind of sac (2 to 8 mm. long) directly under the ventral surface. The pharynx (0·7 mm. long) is preceded by a prepharynx (0·28 mm. long); the œsophagus is very short and the intestinal cæca are simple and present two characteristic curves towards the middle line, one at about the middle of the body, the other between the testes. The genital pore opens on the median line immediately anterior to the ventral sucker. The testes are in the posterior half of the body, one behind the other; both are branched dichotomously. The ovary is branched, and is placed about the middle of the body on the right of the median line. The vitellaria are well developed, and extend from the ventral sucker to the caudal end of the body, where they meet. The acini are very small. The eggs (Fig. 158, *g*) are numerous and measure 120 to 130 μ in length by 77 to 80 μ in breadth; they are closed, I find, by a very delicate operculum.

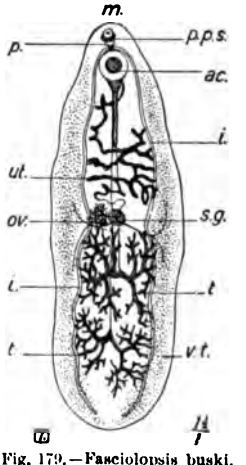


Fig. 179.—Fasciolopsis buski. (*After Odhner.*)

Pathogenesis and treatment.—This parasite inhabits the upper part of the small intestine. In two recorded instances (Cobbold) it was associated with attacks of recurring diarrhœa and other signs of intestinal irritation. The best treatment is thymol or eucalyptus oil, given as in ankylostomiasis.

FASCIOLOPSIS RATHOUISI (Poirier, 1887)

Under the name of *F. rathouisi* a fluke was described by Poirier in 1887. The validity of this species has given rise to a good deal of discussion. Leiper, who has examined the type specimen, believes the so-called distinctive features are solely due to maceration of *F. buski*.

DICROCŒLIUM LANCEATUM (Stiles and Hassall, 1896)

Synonym.—*Fasciola lanceolata.*

History.—*D. lanceatum* was found by Buchholz in the gall-bladder of man in Germany, and has since been noted in Egypt and Italy. It is found commonly in bile-ducts of animals, especially herbivora, in Europe, Africa, and America.

The parasite.—*D. lanceatum* is a small fluke 8–10 mm. in length by 1·5–2·51 mm. in breadth. It is attenuated anteriorly, and the widest point is just posterior to the yolk glands. The intestine bifurcates just in front of the genital pore. The testes lie behind the ventral sucker. The ovary lies behind the posterior testis; there is a receptaculum seminis and a Laurer's canal. The yolk glands lie in the lateral portion of the middle fifth of the body. The eggs are thick-shelled, yellowish-brown in colour, and measure 38–45 μ by 22–30 μ. Nothing is known of the life history of the parasite.

HETEROPHYES HETEROPHYES (Bilh. v. Sieb., 1852)

Synonyms.—*Distomum heterophyes; Dicrocœlium heterophyes; Distoma heterophyes; Heterophyes ægyptiaca; Mesogonimus heterophyes; Cœnogonimus heterophyes; Cotylogonimus heterophyes.*

History.—*Heterophyes heterophyes* was discovered in 1851 in Cairo by Bilharz at the post-mortem of a child.

Geographical distribution.—It has been reported from Egypt, China, and Japan, and probably has a wide distribution.

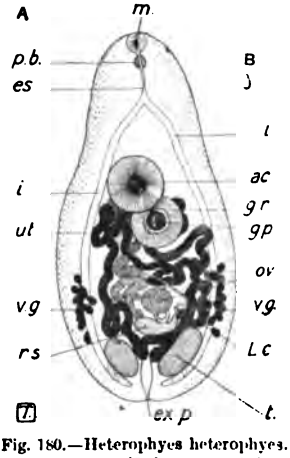


Fig. 180.—Heterophyes heterophyes. A, Greatly magnified; B, natural size.

Zoological distribution.—Looss has found it in Egypt in the dog (*Canis familiaris*), in the cat (*Felis domestica*), in a fox (*Canis niloticus ?*), and in a kite (*Milvus parasiticus*). Janson reports it from the intestine of the dog in Japan, and Yokagawa in Formosa.

The parasite.—*H. heterophyes* (Fig. 180) is the smallest trematode inhabiting man, excepting the newly described *Y. yokagawa*. It measures 1 to 1·7 mm. in length by 0·3 to 0·7 mm. in breadth. It has an oval, elongate shape and a reddish colour. The neck is not sharply defined from the body, and may be greatly outstretched. The oral sucker

(0·09 mm. in diameter) is subterminal and about one-third the size of the ventral sucker (0·23 mm.), which is placed at about the middle of the body. The cuticle is thickly beset with quadrate scales, 5 to 6 μ long by 4 μ broad. The prepharynx is short (80 μ in length); the pharynx measures 50 to 70 μ in length by 40 to 50 μ in diameter. The œsophagus is about three times as long. The intestinal cæca extend to the posterior extremity, where they converge and terminate close to the excretory bladder. The lateral ends of the vitellaria extend beyond the intestinal cæca. The genital pore opens postero-laterally to, and in the immediate vicinity of, the ventral sucker; it is surrounded by a muscular ring. Testicles oval, in extreme posterior end of body. Ovary globular, median and anterior to the testes. Receptaculum seminis as large as the ovary; uterine coils not numerous, and extending between the ventral suckers and the testicles. Eggs light brown, thick-shelled, oval, 20 to 30 μ by 15 to 17 μ; contain a ciliated embryo when oviposited. (Fig. 158, *c*.)

The life history of the parasite is not determined. It seems to have little pathological importance. It inhabits the small intestine.

YOKAGAWA YOKAGAWA (Leiper, 1912)

Synonyms.—*Tocotrema yokagawa; Heterophyes yokagawa; Metagonimus yokagawai* (Katsurada).

This parasite has been found by Yokagawa to be widely spread in the intestinal tract of natives of Korea, Formosa, and Japan. It is believed hitherto to have escaped notice from the resemblance of the egg to that of Clonorchis, and the very small size of the adult. The parasite occurs also in dogs. According to Leiper it belongs to a new genus, *Yokagawa*, characterized by the extraordinary absence of the ventral sucker. He maintains that the genital sucker is highly developed but does not possess the circlet of hooks or "anthus" characteristic of the genus Heterophyes, which in other respects it closely resembles. This description is entirely opposed to that of Yokagawa, who has observed the specimens in a live state and finds that this large disc represents the suctorial ventral sucker, and further, as a result of minute study, on developmental as well as morphological evidence, finds that the genital aperture is situated as a minute slit in the anterior aspect of this ventral sucker. The cercarial stage is passed in fresh-water fish, "ayu" (*Plecoglossus altivelis*), often eaten in the raw state by Japanese. Yokagawa has made an elaborate study of the developmental cycle. The cercariæ have a thin and hyaline appearance, and measure 14–16 mm. in length by 0·126–1 mm. in breadth. They are found attached to the gills, fins, and tails of the fish, much less commonly in the muscles, indicating that the alimentary route is not the usual mode of infection of the fish. Mice and dogs can be infected with the cercariæ. Yokagawa has shown that the cercariæ can withstand the action of the gastric juice, but that the hyaline capsule is

dissolved by its action. The larvæ thus set free develop in the duodenum; they are said to be richly studded with pigment granules. Development is very rapid, and the adult stage is reached in seven to ten days after infection. *Y. yokagawa* is only 1·1 mm. long by 0·42–0·7 mm. broad, and is covered with small spines; in the general disposition of its organs it resembles Heterophyes (Fig. 180); it is easily the smallest fluke found in man. The egg resembles that of *C. sinensis* in size, but is regularly elliptical in shape, dark brown in colour, and the shell membrane has a double contour, and measures 0·028 mm. in length by 0·016 mm. in breadth. *Y. yokagawa* is apparently an innocuous parasite in man, causing at most a catarrhal condition of the intestine canal which it inhabits.

Thymol and naphthol are efficient anthelmintics.

ECHINOSTOMUM ILOCANUM (Garrison, 1908)

Synonym.—*Fasciolotta ilocana.*

This parasite was discovered in 1907 by Garrison, who noticed peculiar eggs in the fæces of Philippine prisoners in the prison at Biliprid, in Manila, and subsequently obtained a small number of trematodes from the intestinal canal. Odhner has recently demonstrated a crown of spines round the oral sucker, and therefore has transferred it to the genus *Echinostomum.* In length it is 4–6 mm. by 0·75–1·35 mm. in breadth. It is attenuated posteriorly. The acetabulum is much larger than the oral sucker. The genital pore opens separately a little behind the halfway point between the pharynx and the acetabulum. Each testis has an anterior and a posterior lobe. The ovary is globular.

Nothing is known about the life history of the parasite, beyond the fact that a miracidium hatches in about ten days after the eggs have left the host.

ECHINOSTOMUM MALAYANUM (Leiper, 1912)

This parasite is found in the intestines of natives in the Malay States, but probably is not normally parasitic in man. The body is 12 mm. long by 3 mm. in greatest breadth, and 1·3 mm. in thickness. Both ends of the body are rounded. There is a row of 43 stout spines round the circumoral disc; they vary in size; those on the ventral are 0·07 mm. and those on the dorsal surface 0·05 to 0·16 mm. in length. The oral sucker comprises one-third of the total diameter of the circumoral disc; it communicates with the spheroidal muscular pharynx by a thin-walled portion 0·175 mm. long. The œsophagus measures 0·04 mm. in length, and bifurcates near the pharynx. The main gut branches are simple and end blindly at the hind end of the body. The ventral sucker, 0·9 by 0·75 mm., is several times larger than the oral. The testes are tandem and are deeply lobed; they are situated in the middle of the body behind the ventral sucker. The cirrus pouch is well developed,

and extends behind the level of the fundus. The ovary has a smooth surface, and lies immediately in front of the anterior testis, 0·85 mm. behind the ventral sucker.

3. CESTODES

The ordinary tapeworms, *Tænia saginata* (Fig. 181) and *Tænia solium*, and their cystic forms, are common enough in the tropics and sub-tropics, their distribution being regulated by the presence or absence of their proper intermediary hosts—the ox in the one case, the pig in the other—and by the habits of the people as regards cooking and conservancy. *Echinococcus granulosus* (= *Tænia echinococcus*) of the dog, and its cystic form — hydatids — are found wherever the dog and the sheep are found, that is practically everywhere. The broad tapeworm (*Dibothriocephalus latus*) is known to occur in Turkestan, in Japan—where the natives are in the habit of eating raw fish—in Madagascar, and among the natives on the shores of Lake 'Ngami, South Africa. Ichthyophagous habits are probably responsible for the occurrence of *Diplogonoporus grandis*, another large dibothriocephalid found by Ijima and Kurimoto in a Japanese from the province of Higen.

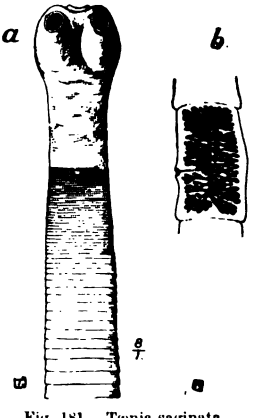


Fig. 181.—Tænia saginata (magnified). (*After Braun.*)
a, Cephalic end; *b*, mature segment (nat. size).

The only cestodes of man which, so far as is known, have any claim to be regarded as more or less special to warm climates are *T. africana*, *T. hominis*, *T. philippina*, *Hymenolepis nana*, *Davainea madagascariensis*, *D. asiatica*, *Sparganum mansoni*, and *S. proliferum*. Doubtless there are other species which so far have escaped observation.

TÆNIA AFRICANA (Linstow, 1900)

History.—*Tænia africana* was described by Linstow in 1900. It was found in German East Africa, in native soldiers stationed at Langenburg, near Lake Nyassa.

The parasite (Figs. 182–3).—*T. africana* differs considerably from the common unarmed tapeworm of man. Its strobila attains 1·4 metres in length, and is composed of about 600 proglottides. The scolex is quadrilateral, unarmed, very small (1·38 mm. broad by 0·47 mm. long), and is provided with an apical sucker (0·16 mm.) in addition to the usual four suckers (0·63 mm.). The neck is very short, and somewhat broader than the scolex. The proglottides are all broader than they are long. Immediately at the back of the scolex they measure 0·16 mm. in length by 1·78 mm. in breadth and 0·59 mm. in thickness; about the middle of the strobila they are 3 mm.

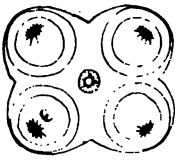


Fig. 182.—Tænia africana. (*After Linstow.*)

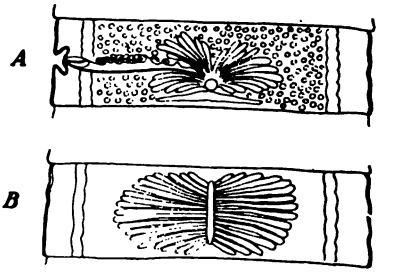


Fig. 183.—Tænia africana.
A, Frontal section of mature segment.
B, " " gravid "

long by 9 mm. broad and 1·20 mm. thick. The terminal and gravid strobila are 7 mm. long by 12 to 15 mm. broad and 1·35 mm. thick. The genital pores alternate irregularly, and are placed in the middle of the border of each segment. The testicles are very numerous and scattered throughout the middle layer. The vas deferens is much convoluted. The cirrus pouch is pyriform and thick-walled. The cirrus and vagina are beset with bristles directed outwards. The receptaculum seminis is fusiform. The ovary consists of two fan-shaped wings, composed of club-shaped tubes centering towards the shell-gland; the latter is median and globular. The uterus includes a median stem and 15 to 24 lateral, unramified branches, which are longer than the stem, and spread out like a fan. The ova are spherical, the embryophore 31 to 39 by 33·8 μ, with thick radially-striated shell; hooks of the onchosphere measure 7·8 μ in length.

The cystic stage of this tapeworm is unknown. Linstow suggests that it may be found in the zebu (*Bos indicus*), the flesh of which the natives are in the habit of eating raw.

TÆNIA HOMINIS (Linstow, 1902)

History.—*T. hominis* was described by Linstow in 1902, from a specimen obtained from the intestine of man in Aschabad, Asiatic Russia.

The parasite (Fig. 184).—The strobila examined by Linstow was immature; it measured 70 mm. in length. The scolex measured 1·34 mm. in length by 2 mm. in breadth, and exhibited a rudimentary unarmed rostellum. At the back of the suckers there was a characteristic circular ridge. The genital organs were not developed.

The cystic form is unknown.

Fig. 184.—Tænia hominis, head. (*After Linstow.*)

TÆNIA PHILIPPINA (Garrison, 1907)

This parasite was found by Hare in the prison at Biliprid, Manila. It is 80–100 cm. in length. The head is cube-shaped with unarmed retractile rostellum and four suckers. The neck is segmented. The proglottides number about 800; the mature proglottides are 4–5 mm. in width by 0·8–1 mm. in length. The surface and margins extend posteriorly in an elongated cuff-like projection over the succeeding segment. The testes are 130–160 μ in length and 60–80 μ in breadth; the vas deferens is without a vesicula seminalis. The cirrus pouch is absent. The genital pore is situated irregularly on the lateral borders. The vagina is coiled and without setæ. The mature uterus is very compact with a median stem and numerous long, slender dichotomous branches.

HYMENOLEPIS NANA (v. Siebold, 1852)

Synonyms.—*Tænia nana; Diplacanthus nanus; Hymenolepis murina.*

History.—This minutest of the tapeworms inhabiting man was first found as a human parasite by Bilharz, in Cairo, in 1851. The following year it was described by von Siebold, who proposed to call it *Tænia nana.* In 1887, Grassi identified it with *Hymenolepis murina* of the rat, and showed that it can dispense with an intermediary host, the larva penetrating into a villus of the rodent's intestine to become a cysticercoid, and then re-entering the canal to become transformed into the adult stage.

Zoological distribution.—*H. nana* is found in the brown rat (*Mus decumanus*), black rat (*M.*

rattus), house mouse (*M. musculus*), dwarf field mouse (*M. minutus*) and garden dormouse (*Eliomys quercinus*).

Geographical distribution. — *H. nana* is found in Egypt, Siam, Japan, the southern States of the American Union, Brazil, Argentine, and throughout Europe, but more especially in the warmer parts, as in Sicily, where, according to Calandruccio, 10 per cent. of the children are affected.

The parasite (Fig. 186).—The strobila vary in length from 5 to 45 mm. with the number of proglottides, which may be from about 100 to 200. The scolex is subglobular and measures 139 to 480 μ in diameter; it is provided with a well-developed rostellum armed with a single crown of twenty to thirty hooklets 14 to 18 μ long; the suckers are globular and have a diameter of 80 to 150 μ. The neck is long. The proglottides are very short anteriorly; farther down the chain they increase in size but remain broader than long. Only the hindermost segments may equal or even slightly exceed their breadth. The maximum breadth of the proglottides is from 0·5 to 0·9 mm. The genital pores open on the left margin near the anterior border of each segment. There are three testes in each segment; the vas deferens widens to form a seminal vesicle within the cirrus pouch. The gravid uterus occupies nearly the entire segment. The eggs number from 80 to 180 in each proglottis; they are oval or globular, and present two distinct membranes; the outer one measures from 30 to 60 μ in diameter, the inner one from 16 to 34 μ. The latter exhibits at each pole a more or less conspicuous mammillate projection.

Development. — The development of *Hymenolepis nana* has been worked out experimentally by Grassi in the rat. The egg is swallowed, and after hatching enters a villus in the lower part of the small intestine (Fig. 185), where it transforms into a cercocystis.* The six-hooked embryo is found encysted from 24 to 50 hours after ingestion, its long axis corresponding to that of the villus, and the posterior end bearing the embryonal hooks directed towards the lumen of the intestine. Occasionally two parasites may be found in the same villus. In about 40 to 70 hours after ingestion the scolex has appeared, and in 80 to 90 hours after ingestion the rostellum is provided with hooklets. Then the parasite passes into the lumen of the intestine, where it can be seen attached to the epithelium of the villus with short neck and no trace of segmentation. The rapidity of development varies somewhat, and, as a rule, various stages are found occurring simultaneously in the same host. Strobilization is rapid: the proglottides attain maturity in about 10 or 12 days, and about 30 days after infection the

* The term *cercocystis* was introduced by Villot to designate those cysticercoids which are provided with caudal appendages.

eggs of the parasite begin to appear in the fæces. These never develop in the same host unless reintroduced per os or through a reverse peristalsis, because, as in *Oxyuris vermicularis*, the embryo will not hatch unless the egg be subjected to the action of the gastric juices. Young white rats proved most susceptible to the infection, whilst rats already harbouring the parasites were refractory. Grassi's observations do not entirely disprove the possible agency of an intermediary host as in other tapeworms, but they certainly show that it can be dispensed with, and indeed that as a rule the rat acts both as definitive and intermediary host. Experiments in man were not conclusive. Out of eight persons fed with eggs or mature segments of the parasite both from man and rats only one became infected. This occurred, however, in a region (Catania) where many harbour this tapeworm.

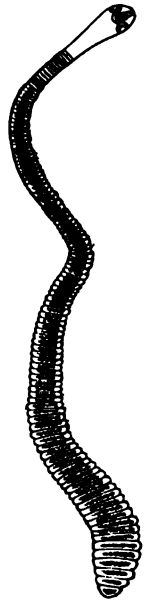


Fig. 186.—Hymenolepis nana (magnified).

Pathogenesis. — *H. nana* is very minute, but as a rule it occurs in large numbers—usually

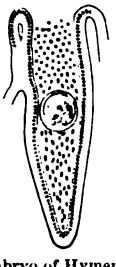


Fig. 185.—Embryo of Hymenolepis nana in small intestine.

hundreds, not infrequently thousands. When attached to the intestine it fixes its rostellum deeply into the lumen of a Lieberkühn's follicle, thus altering and destroying many of the epithelial cells. It is obvious, therefore, that a number of these worms must give rise to considerable irritation and possibly favour secondary infection. According to Grassi, *H. nana* may bore deeply into the mucosa; and at the post-mortem of a case in which 400 specimens were found

in the ileum, Visconti and Segré noticed that the mucosa throughout the small intestine was tumefied, hyperæmic, and covered with a thick layer of greyish mucus, through which the worms were scattered. The most frequent symptoms reported by authors are abdominal pain, which may or may not be associated with diarrhœa; convulsions of various sorts, frequently epileptiform; headache and strabismus. The nervous phenomena are ascribed to the absorption of toxic products elaborated by the parasite. On account of its small size this parasite is easily overlooked. Diagnosis is based on the presence of the characteristic ova in the fæces. Some care is requisite in looking for the eggs, because, owing to their transparency, they may escape observation.

Treatment.—*H. nana* is readily expelled by male fern. If a patient harbours this parasite he should not be allowed to sleep in the same bed with another person. On prophylactic grounds rats and mice should be banished from the house, and all food kept out of their reach.

DAVAINEA MADAGASCARIENSIS (Davaine, 1869)

Synonyms.—*Tænia madagascariensis; T. demerariensis.*

History.—*Davainea madagascariensis* was first described by Davaine in 1869 from fragments of two strobila without heads sent to him by Grenet, who discovered it at Mayotte, Comoro Islands, in two Creole children. In 1891 Leuckart described an entire specimen with scolex which was sent to him from Siam. But it is chiefly to Blanchard that we owe our knowledge of this parasite.

Geographical distribution.—The first two cases published were those of Grenet at Mayotte, but both came from abroad. One of them was an eighteen-months-old child who had arrived from the Antilles five months previously, the other a little two-year-old girl from Réunion who had landed two months previously. The next four cases were seen at Port Louis (Mauritius) by Chevreau, who looked for the parasite at Blanchard's suggestion. All these cases occurred in children, two of whom were only 5 years old. The seventh case, published by Leuckart, occurred at Bangkok (Siam) in a three-year-old boy, the son of a Danish sea-captain. The eighth was that of Daniels, who discovered the worm in an adult native at Georgetown (British Guiana). A further specimen was described by Blanchard, who found it in Davaine's collection with the following label: "Nossi-Bé (Island), Novem-

ber, 1873; passed by a little girl 3 years old." Recently Garrison has described two cases in the Philippines.

Zoological distribution.—As yet *D. madagascariensis* has only been found in man, but the genus is widely distributed in mammals and birds. Amongst mammals it is found in rats (*Mus siporanus*, *Mus rajah*), in hares (*Lepus sylvaticus*, *L. arizonæ*, *L. melanotis*), in the pangolin (*Manis pentadactyla*). Amongst birds it is found in the ostrich (*Struthio camelus*), the common rhea (*Rhea americana*), the emu (*Dromæus novæ hollandiæ*), the little egret (*Ardea garetta*), the grey parrot (*Psittacus erithacus*), and in fowls, pigeons, turkeys, pheasants, partridges, grouse, woodpeckers, blackbirds, starlings, and quails.

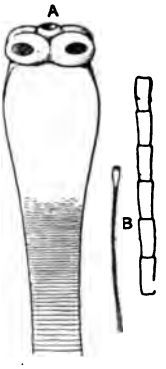


Fig. 187.—Davainea madagascariensis. (*After Blanchard.*) A. Head; B, nat. size.

The parasite (Fig. 187).—The strobila attains 25 to 30 cm. in length by 1·4 mm. in breadth, and is composed of 500 to 600 proglottides. The scolex is provided with four large round suckers and a retractile rostellum surrounded by a double crown of 90 hooklets 18 μ long. The rostellum when invaginated forms a kind of pouch which gives it the appearance of an apical sucker. In the two specimens examined no hooklets were seen round the suckers, and in one the rostellum was unarmed. This may be on account of the caducity of the hooks. The neck is very wide, thick, depressed antero-posteriorly and furrowed laterally. The proximal segments are broader than long, the distal longer than broad (2 by 1·4 mm.). The last 100 proglottides are gravid and form one-half the length of the entire strobila. They resemble apple-seeds in shape. The genital pores are unilateral and open near the proximal corner of each segment. The cirrus pouch is fusiform, the ductus ejaculatorius very long and sinuous, the testicles over 50 in number. The receptaculum seminis is unusually long and broad; it extends to the middle of the segment and communicates with the oviduct. The uterus is composed of a number of tubes rolled up on each side into an almost spherical coil. When filled with ova the windings of the uterus unroll and extend throughout the proglottis; they then lose their walls, so that the eggs come to lie free in the parenchyma. The eggs then become surrounded, singly or in small groups, by parenchymatous cells forming egg-balls, of which from 300 to 400 may be present in each segment. The globular onchosphere (8 μ to 15 μ) is surrounded by two perfectly transparent shells, the outer one bearing two pointed projections.

The cystic stage is unknown. Blanchard suggests that

it might be found in cockroaches (*Periplaneta orientalis*, *P. americana*, etc.). He points out that the parasite has a wide distribution within the tropics, and that cases of infection have occurred in islands, in seaports, and on board ship. The cockroach is cosmopolitan in distribution, it infests ships and contaminates food. Other tapeworms of the genus Davainea are known to spend their larval stage in insects and molluscs. According to Grassi and Revelli, some of these tapeworms, as, for instance, *D. proglottina* of fowls, may dispense with an intermediary invertebrate host and spend both their larval and adult stages within the body of the same host.

Pathogenesis.—We know nothing of the pathogenesis of this form of tæniasis. The parasite has been found almost exclusively in young children.

DAVAINEA ASIATICA (Linstow, 1901)

Synonym.—*Tænia asiatica.*

History.—*Davainea asiatica* was described by Linstow in 1901, from a specimen in the Zoological Museum of the Imperial Academy of Science in St. Petersburg. It was passed by a man in Aschabad (Asiatic Russia, near the northern frontier of Persia), and preserved by Anger.

Fig. 188. — Davainea asiatica, sagittal section of gravid segment. (*After Linstow.*)

The parasite (Fig. 188).—The specimen examined by Linstow measures 29·8 cm. in length, and is composed of 750 segments. The scolex is missing. The proglottides are all broader than long, measuring 0·16 mm. in width at the proximal end, and 1·78 mm. at the distal end. The posterior margin of each segment extends over the anterior margin of the next following segment. The genital pores are unilateral and open in the proximal third of each proglottis. The testicles (35 to 44 μ in diameter) are arranged in a ventral and dorsal layer of about eight rows each. The vas deferens extends in convolutions about one-third across the segment; the cirrus pouch is pyriform; the ovary extends across the segment between the ventral canals. The vagina forms a large fusiform receptaculum seminis. The uterus breaks up into 60 to 70 egg-balls in each segment. Mature eggs were not observed.

The cystic form is unknown.

INTESTINAL MYIASIS

A residence in the alimentary canal of some vertebrate animal is a regular feature in the life history of many dipterous insects. The ova of the

insect are either licked from the skin, or swallowed in the food on which they had been deposited. In this way they get transferred to the stomach, where, after a time, the larva is hatched out and undergoes development. In due course it appears in the fæces. Man is not infrequently victimized in this way, especially in tropical countries. Sometimes, until a correct diagnosis is arrived at, not a little alarm is caused by the appearance of these creatures in the stools. They are easily recognized. The ringed, cylindrical body, from ½ in. to 1 in. in length according to species, broad at one end, tapering at the other, and usually beset with little spines or hairs, is sufficiently diagnostic. (Fig. 189.)

Already we know over twenty species of diptera whose larvæ have been found in or expelled from the human intestinal canal. In Europe the majority of cases of intestinal myiasis, a not infrequent occurrence, are caused by *Fannia canicularis* (a fly closely resembling the common house-fly and erroneously considered a young form of the latter on account of its smaller size), and the closely related *F. scalaris*. Austen believes that intestinal myiasis, due to the larvæ of these flies, is probably to be traced to the parent flies having oviposited on the anus when the patient has been using some country privy where such insects are common.

Fig. 189.—Larva of Calliphora vomitoria.

A dose of castor oil will probably suffice to expel any of these creatures that may not have been passed spontaneously.

A rational prophylaxis would consist in the covering up of food after it has been cooked, in order to prevent the access of flies.

Instances in which the larvæ have been discharged per urethram have also been met with, though more rarely.

Section VI.—SKIN DISEASES

CHAPTER XLVI

DISEASES OF THE SKIN

1. NON-SPECIFIC

PRICKLY HEAT

Prickly heat or, as it is sometimes called, lichen tropicus, is probably a form of miliaria (not of lichen) connected with the excessive sweating incident to the heat of tropical climates. According to Pollitzer, the mechanism of its production depends on the non-cornification of the cells of the stratum corneum, the individual cells of which, in consequence of their being sodden by constant perspiration, swell and so obstruct the orifices of the sweat-glands, thereby leading to accumulation of sweat in the ducts. Pearse regards the disease as an acute distension of the sebaceous glands by their own secretion; the glands, he holds, are over-stimulated in order to supply an adequate amount of sebum to the skin, so as to make up for the loss of that material washed away by inordinate sweating. Durham regards prickly heat as an infective disease produced by a minute and very active amœba, readily found in the fluid of the vesicles provided search is made before the contents become turbid.

Nearly every European in the tropics suffers from prickly heat, particularly during the earlier years of residence. Some never seem to become acclimatized in this respect, but continue year after year to exhibit their crop of prickly heat lesions when the hot season comes round.

Though sufficiently annoying in the robust and healthy, in them prickly heat is not a grave affair. It

is otherwise in the case of the invalid, of delicate sickly children, of hysterical and, especially, of parturient women; to these it may prove, by interfering with sleep and provoking restlessness, a very serious matter. Prickly heat is also a common though indirect cause of boils; for the breaches of surface, following on the scratching it induces, afford many opportunities for the invasion of the micro-organisms of that disease.

Prickly heat consists of a miliary-like eruption, generally most profuse on those parts of the body, as around the waist, which are closely covered with clothing; but it also occurs on the backs of the hands, arms, legs, forehead, occasionally on the face, the scalp, in fact on any part of the surface of the body except the palms and soles. The minute, shining, glass-like vesicles, and the numerous, closely set and slightly inflamed papules, give the skin the feeling as if thickly sprinkled with grains of sand. The eruption may keep out for months on end, becoming better or worse according to circumstances. The pricking and itching are often exceedingly distressing. Anything leading to perspiration immediately provokes an outburst of this almost intolerable itching — nothing more certainly than a cup of hot tea or a plate of hot soup. Long drinks, exposure to the hot sun, close rooms, warm clothing, all aggravate the distress. Sometimes the little vesicles may pustulate, doubtless from micrococcus infection. So soon as the weather becomes cool the eruption and the irritation quickly subside.

Treatment.—Manifestly the most important thing is the avoidance of all causes of perspiration —particularly the copious consumption of fluids, especially hot fluids—moderation in exercise, avoiding sea bathing, close rooms, warm clothing, and so forth. Soap should not be used in the bath. The sleeping-mattress and pillow should be covered with a finely woven grass mat, and the bed provided with what is known in the East as a "Dutch-wife"—that is, a hollow cylinder, 4 ft. by 8 or 10 in., of open rattan work, over which the arms and legs can be thrown

and unnecessary apposition of sweating surfaces so avoided. A punkah at night is a great comfort. Many things have been recommended as preventives; for example, rubbing the body over after the bath with the juice of a lemon, Jeyes' fluid or bran in the bath, etc. Every bath-room in the tropics should be provided with some mildly astringent and antiseptic dusting powder. A very good one consists of equal parts of boric acid, oxide of zinc, and starch. This should be freely applied, after careful drying of the skin, particularly to the axillæ, crutch, under the mammæ in women, and between the folds of skin in fat children and adults. A simple precaution of this sort saves much suffering both from prickly heat and epiphytic skin disease.

Durham recommends painting the patches with weak iodine or, better, rubbing in solution of corrosive sublimate, 1 in 500 to 1 in 1,000: this he found very efficacious, curing the disease with certainty after one or two applications. He suggests the use of some form of obstetric soap as being less liable to lead, through inadvertence, to accidental poisoning.

Castellani advises the frequent application of a salicylic acid (ʒi) and spirit (℥viii) lotion. Pearse strongly recommends the inunction of a mixture of almond oil and lanoline in the proportion of 8 to 1, and scented according to fancy. St. George Gray finds thin flannel a better wear than cotton or linen as a preventive of prickly heat. Sometimes the following powder, gently rubbed in for five or ten minutes with a damp sponge, cures bad patches of prickly heat: Sublimed sulphur, 80 parts; magnesia, 15 parts; oxide of zinc, 5 parts. Lotions of calamine, with or without hydrocyanic acid, or of carbolic acid, relieve the itching temporarily.

2. BACTERIAL

Tropical Sloughing Phagedæna

Definition.—A rapidly spreading but, as a rule, after a time, spontaneously arrested gangrene of the skin and subjacent tissues, resulting in the formation

of a large sloughing sore. Though occasionally fatal, these sores almost always, under favourable conditions, granulate and cicatrize, or become chronic ulcers.

Geographical distribution. — Sloughing phagedæna is common in most tropical countries, particularly in those with a hot, damp climate. These sores are often named after those districts in which they are specially prevalent; thus we hear of Mozambique ulcer, Yemen ulcer, etc. They are found principally in jungle lands, less frequently in towns and well-settled districts. Whether tropical sloughing phagedæna and hospital gangrene, at one time so prevalent in the hospitals of Europe, are the same disease, it is difficult to say. They agree in some respects; but in the marked tendency of the tropical sore to self-limitation, and, possibly, as Scheube points out, in its relatively feebly infective power, there is some indication of a specific difference.

Occasionally this disease assumes epidemic proportions. Thus, Lloyd Patterson (*Ind. Med. Gaz.*, Nov., 1908) described one such epidemic which "swept like a plague up the whole of Assam," seriously interfering with the efficiency of the labour force on the tea plantations.

A variety of bacteria and spirochætes have been described as possible germ causes of this disease. Vincent remarked the frequent concurrence of spirochætes and fusiform bacilli in the sores, an observation confirmed by several others, including Todd and Wolbach on the Gambia. Prowazek attributes these ulcers to *Spirochæta schaudinni.*

Lloyd Patterson has called attention (*loc. cit.*) to a bacillus occurring in scrapings from the base of the ulcers, which he considers as the probable germ, and which had hitherto been overlooked in consequence of the difficulty in staining it, prolonged immersion in Leishman's stain being necessary. Although sloughing phagedæna is evidently a germ disease, it is not readily communicated by ordinary inoculation either to man or to the lower animals. Apparently a concurrence of certain unknown conditions is essential. Lloyd Patterson, however, by bandaging

a swab smeared with discharge from a typical sore (discharge containing large numbers of his bacillus) on to the surface of an abrasion from which the scab had been removed, succeeded in producing a characteristic sore, in the discharge from which his bacillus was present in great profusion.

Etiology.—Doubtless depending on the proliferation in the affected tissues of some specific micro-organism, not yet satisfactorily separated, the germ of sloughing phagedæna attacks the healthy as well as the debilitated, young or old, male or female. It finds its special opportunity in the bodies of men who, from overwork, underfeeding, exposure, malaria, dysentery, scorbutus, and the like, are physically depressed. Thus it is apt to attack the half-starved, malaria-stricken pioneers in jungle lands, overdriven slave gangs, and soldiers campaigning in the tropics. In such circumstances a slight wound, an abrasion, even an insect bite, or an old chronic ulcer may serve as the starting-point for one of these terrible sores. Where yaws and sloughing phagedæna are co-endemic, the sores of the former may become infected with the virus of the latter, and serious sloughing and cicatricial contractions result. The feet and legs, being most exposed to injury, are the most frequent locations for this form of ulceration; but the arms or any other part of the body may also be attacked.

Symptoms.—If the disease occur in previously sound skin the first indication is the formation of a larger or smaller bleb with sero-sanguinolent contents. The formation of this may be attended with some pain and constitutional irritation. When, in the course of a few hours, the bulla ruptures, an ash-grey, moist slough is exposed. The sloughing process rapidly extends in all directions until the skin and subcutaneous fascia over an area of an inch to many inches in diameter are converted into a yellowish, moist, horribly stinking slough. After a few days the centre of the slough begins to liquefy, the sore still continuing to extend at the periphery. In the course of a week or longer the sloughing process may

cease and the slough be gradually thrown off. Then it is seen that not only have the skin and superficial fascia been destroyed, but that in bad cases possibly muscles, tendons, nerves, vessels, and even the periosteum of the bones, have shared in the gangrenous process. Fortunately in many instances the deeper structures are spared, the disease being relatively limited and superficial. Sometimes, however, important structures, including joints, bones, and large blood-vessels, are destroyed; in such cases, even if life be spared, great deformity may ensue from different forms of ankylosis, or from strangulation of a distal part by a contracting cicatrix.

When the disease attacks a pre-existing wound or sore, the granulating surface of this becomes dry, and rapidly assumes the appearance and characters of a slough.

In sloughing phagedæna the neighbourhood of the sore is somewhat congested and swollen, particularly so if the patient has been obliged to use the limb. Constitutional disturbance may be considerable and of an adynamic type. On the other hand, it occasionally happens that large sores are attended with singularly slight local or general reaction. In bad cases a sapræmic condition is apt to supervene and carry off the patient; or death may occur from bleeding from the opening of a large blood-vessel.

Treatment.—It is of the first importance to endeavour to correct any cachectic state which may be present. Thus good food, fresh vegetables, lime-juice, and quinine are almost invariably indicated. Opium in full doses, not merely to assuage pain, but on account of its special action on the phagedænic process, is usually of great service. Locally, an endeavour must be made effectually to destroy the germ by the application of some powerful and penetrating caustic to the diseased surface. With this view, on the strength of considerable experience, I recommend that the patient be put under chloroform and the slough thoroughly dissolved off by the free application of pure carbolic acid, a piece of lint on a stout stick being used as a mop for the purpose.

Thereafter the limb should be elevated and placed under some improvised irrigator from which a weak, warm antiseptic solution should continuously trickle over the now clean surface. If the phagedænic action recur the carbolic acid must be promptly reapplied as often as may be necessary. On healthy granulations springing up the ulcer is to be treated on ordinary principles. Lloyd Patterson recommends a dressing of carbolic oil after the initial cauterization, and subsequently, when the sore is clean, a dressing of lead-foil such as is used for lining tea-chests.

Patients with this disease should be regarded as infective, and, so far as possible, isolated.

Boils

The anatomical and clinical features of this painful affection are too familiar to require detailed description. Suffice it to say that a boil is produced by the proliferation of *Staphylococcus pyogenes aureus* and *albus*, *Streptococcus pyogenes*, or other pyogenic micro-organisms in the skin and subcutaneous tissue; that the organism gives rise to local and limited infiltration of the tissues with lymph which subsequently and rapidly dies, the necrotic core being surrounded by an areola of acute inflammation; that this core is separated by a process of sloughing and so got rid of, the resulting ulcer speedily healing and leaving a depressed scar, which, when occurring about the legs, may become pigmented. Though a self-limiting disease locally, it is nevertheless capable of being inoculated elsewhere in the same individual, both through a breach of surface and, also, by simple contact of the discharges with the skin, the micro-organism apparently entering by a hair follicle. This auto-inoculability of boils is apt to be overlooked.

Conditions of debility, presumably by lowering resistance, predispose to boils; the subjects of diabetes are specially prone to them, the saccharine state of the blood or secretions seeming to be particularly favourable to growth of the specific germ.

Few Europeans in the tropics escape an attack of boils at one time or another. In some instances crop after crop succeed one another, the individual boils being so numerous that the patient is quite unfitted for work by the attendant pain and fever. In certain years so many members of a community are attacked that the disease may be described as being epidemic. These epidemics, occurring when some particular fruit is in season, are very generally, but probably incorrectly, attributed to the use of the fruit in question. Mangoes, probably erroneously, are frequently held responsible.

Treatment. — Any constitutional irregularity must be treated appropriately. Malaria demands quinine; anæmia and debility, iron and wine; constipation, aperients; diabetes, a suitable diet. I have never seen any good from such vaunted specifics as calcium sulphuret, tar water, or yeast.

Boils ought never, unless in very exceptional circumstances, to be poulticed. Poulticing, although it may relieve the pain of the existing boil, is prone to be followed by more boils in the area sodden by the heat and moisture. Neither should boils be incised or squeezed. The only exception to the rule for not cutting is in the case of boils occurring in the scalp or in the axilla. In the former situation, unless opened early, they are apt, especially in young children, to burrow and cause troublesome abscesses; in the latter situation boils tend to be very indolent and painful, and do not readily spontaneously break through the lax integuments.

In any situation in which the boil is liable to be irritated by pressure or clothing, it is sometimes a good plan to cover the part with a circle of wash-leather spread with soap plaster, and having a small hole cut in its centre corresponding to the apex of the boil. When a boil opens, the discharge must be kept from soiling the adjoining skin, and the patient must be warned against touching the skin elsewhere with pus-soiled fingers. The parts must be frequently cleansed with 1-in-1,000 corrosive sublimate lotion, powdered with boric acid and covered with a dry,

absorbent antiseptic dressing. A threatening boil may often be aborted by touching the little initial itching or vesiculated papule with some penetrating antiseptic, as iodine tincture, or by painting it with collodion. A very successful method is to drill slowly into the centre of the papule with a pointed pencil of hard wood dipped in pure carbolic acid. The point of the pencil should penetrate at least an eighth of an inch, and should be frequently recharged with the acid during the drilling process; the pain is trifling. In this way, in a severe attack of furunculosis, boil after boil may be aborted and the attack brought to an end. In obstinate chronic furunculosis excellent results have occasionally attended treatment conducted on Wright's method of exalting the opsonic index of the blood by injections of killed cultures of the patient's pyogenic micro-organisms.

In severe cases change of air may be necessary.

Pemphigus Contagiosus

Definition. — A non-febrile, highly contagious skin disease peculiar to warm countries. It is characterized by the formation of large vesicles or bullæ which are unattended by marked inflammation, ulceration, or the formation of crusts or scars.

Geographical distribution.—Pemphigus contagiosus is very common in South China during the hot weather; in some years it may even be described as epidemic. It is perennial in the Straits Settlements, and it is known in Ceylon, Madras, in North Queensland, Japan, and America. Doubtless, although it has escaped notice by most medical writers, it is common enough elsewhere in the tropics, or wherever heat and moisture combine to bring about a state of skin favouring its development on the infective material being applied. It is especially common in schools and similar institutions where large numbers of children are thrown much together; they readily pass the disease one to the other. European children are more prone to it than native children; European adults are by no means exempt, but the native adult is rarely affected.

Symptoms. — Pemphigus contagiosus closely resembles certain forms of the impetigo contagiosa of temperate countries, and is doubtless a variety of this class of skin disease. The individual lesions, as can readily be ascertained by inoculation experiments, begin as minute erythematous specks, which rapidly proceed to the formation of vesicles, bullæ, or even large pemphigus-like blebs. The little blister springs abruptly from sound skin; there is no, or very little, areola of congestion. For a short time the hemispherical bleb is beautifully pellucid, tense, and shining. Presently the serous contents become somewhat turbid, and the blister gets flaccid and dull. At this stage, from scratching or from pressure, the blister is generally ruptured. The morbid process does not at once come to an end, but proceeds as an advancing, eccentrically spreading exfoliation of the epidermis; an exfoliation which may not cease to advance until an area an inch or more in diameter is denuded of epithelium. Then, in that particular spot, the disease stops, a pinkish, slightly glazed-looking patch, rarely covered with a tissue-paper-like scale, remaining for some time. Occasionally, after the rupture of the primary bleb, vesication may continue in the peripheral portion of its remains. Only one or two blebs may be visible on the entire surface of the body; generally there are many, the disease being spread by the fingers in scratching or rubbing.

Pemphigus contagiosus may occur in almost any part of the body. In young children it is usually diffuse; in adults it is mostly confined to the axillæ and crutch. In these situations it gives rise to much irritation and discomfort, owing to the successive crops of bullæ running into each other and rendering the parts raw and tender, and predisposed to boils or some form of eczematous intertrigo. During warm, moist weather it may be kept up indefinitely by auto-inoculation.

Assistant-Surgeon Soorjee Narain Singh describes a series of cases of a form of contagious pemphigus occurring in rapid succession in the children of three families in India (exact locality not specified), which

bears some resemblance to the pemphigus contagiosus above described. It differs, however, inasmuch as in the Indian disease the bullæ were very large—often larger than hen's eggs—and persisted for from one to three weeks. In one of the thirteen cases described there followed a certain amount of sloughing at the seat of the bullæ; in the others there was neither ulceration nor constitutional disturbance.

Etiology and pathology.—Like ordinary impetigo contagiosa, this is undoubtedly a germ disease. I have found a diplococcus in the epidermis and fluid of the blister; whether this is the special bacterium responsible for the disease, cultivation and inoculation experiment have not yet decided. The Leishman body has been found in the contents of the blebs. Its presence there has probably no etiological significance so far as this special lesion is concerned.

Diagnosis. — Absence of constitutional symptoms, or a history of such, distinguishes pemphigus contagiosus from chicken-pox. Absence of trichophyton elements and of a well-defined, slightly raised, festooned and itching margin, together with the presence of large blebs and scaling of the epidermis, distinguish it from ordinary forms of body ringworm—a disease with which, when occurring in the armpits and crutch in adults, it is frequently confounded.

Treatment.—Cleanliness, the frequent use of a bichloride of mercury lotion (1 to 1,000), and a dusting powder of equal parts of boric acid, starch, and zinc oxide, are speedily effective. In the school and nursery those responsible for the care of children must be informed of the contagiousness of this unpleasant affection, and measures be instituted accordingly.

3. FUNGOUS

MYCETOMA

Definition.—A fungous disease of warm climates, affecting principally the foot, occasionally the hand, rarely the internal organs or other parts of the body. It is characterized by enlargement and deformity of the part; an oily degeneration and

general fusion of the affected tissues; the formation of cyst-like cavities communicating by sinuses, and containing peculiar mycotic aggregations in an oily purulent fluid which escapes from fistulous openings on the surface. The disease runs a slow course, is never recovered from spontaneously, and, unless removed, terminates after many years in death from exhaustion.

History and geographical distribution.—The earliest notice of this disease we owe to Kæmpfer (1712). Its more modern history commenced with Godfrey, of Madras, who, in the *Lancet* of June 10th, 1843, gave a description of several unquestionable examples under the title, "Tubercular Disease of the Foot." Subsequently, Balingall (1855), who was the first to suggest its parasitic nature, Eyre (1860), and others added considerably to our knowledge of the subject. The merit of bringing the disease prominently before the profession, and of distinctly describing its clinical and anatomical features, as well as of suggesting its true pathology, belongs entirely to Vandyke Carter, who, from 1860 to 1874, in a series of important papers, furnished the information on which all later descriptions have been principally founded. Carter was the first to point out the presence of mycotic elements in the discharges coming from the implicated structures, and in the contents of the characteristic cysts and sinuses with which they are honeycombed, and showed that the disease was allied to actinomycosis. Recently much information has been supplied by Wright, Nicolle, Laveran, Bouffard, and, especially, by Brumpt (*Arch. du Parasitologie*, Trans. X., 1906).

In India mycetoma is endemic in districts more or less limited. These districts are scattered over a wide area, the intervening regions—in some instances whole provinces, as that of Lower Bengal—enjoying an almost complete immunity. It appears to be acquired only in rural districts, the inhabitants of the towns being exempt. Among the most afflicted districts may be mentioned Madura—hence the name "Madura foot" by which mycetoma is often known—Hirsar, Ajmeer,

Delhi, various places in the Punjab, Kashmir, and Rajputana. In recent years we have accounts of its occurrence with some degree of frequency in Senegambia, Somaliland, Algeria, Egypt, the Soudan, Cochin China, Italy, the United States, and South America. It is probable that in time mycetoma will be found to be endemic in many warm countries in which it has hitherto escaped recognition.

Symptoms.—Mycetoma begins usually, though by no means invariably, on the sole of the foot. The first indication of disease is the slow formation of a small, firm, rounded, somewhat hemispherical, slightly discoloured, painless swelling, perhaps about ½ in. in diameter (Fig. 190). After a month or more this swelling may soften and rupture, discharging a peculiar viscid, syrupy, oily, slightly purulent, sometimes blood-streaked fluid containing in suspension certain minute, rounded, greyish or yellowish particles, often compared to grains of fish-roe. In other examples of the disease the particles in the discharge are black, having the size and appearance of grains of coarse gunpowder. Sometimes these particles are aggregated into larger masses up to the size of a pea. In time additional swellings, some of which break down and form similar sinuses, appear in the neighbourhood of the first or elsewhere about the foot. For the most part the sinuses are permanent, healing up in a very few instances only. Gradually the bulk of the foot increases to perhaps two or three times the normal volume (Fig. 190). There is comparatively little lengthening of the foot; but there is a general increase in thickness, so that in time the mass comes to assume an ovoid form, the sole of the member becoming convex, the sides rounded, and the anatomical points obliterated. The toes may be forced apart, bent upwards at the tarso-phalangeal joints, or otherwise misdirected; so that on the foot being placed on the ground the toes do not touch it. The surface of the skin is roughened by a number of larger or smaller, firmer or softer hemispherical elevations, in some of which the orifices of the numerous sinuses open. Most of these orifices are easily

Fig. 190.—Mycetoma of about two years' standing. (*After Legrain.*)

made out; others are not so apparent, their position being indicated and, at the same time, concealed by a bunch of pale, flabby, fungating, and but slightly vascular granulations. In the latter the orifice may be hard to find. Once the probe is got to enter, the instrument readily passes to a considerable depth, even to the bone; in advanced cases it can be carried through the softened tissues with the greatest ease in almost any direction, and without causing much pain or hæmorrhage.

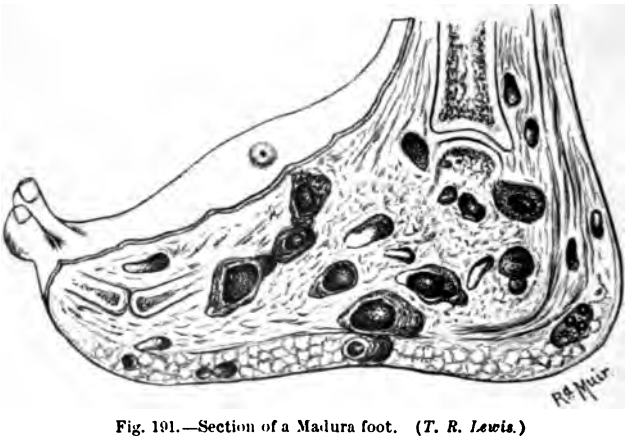


Fig. 191.—Section of a Madura foot. (*T. R. Lewis.*)

The discharge issuing from the sinuses differs in amount in different cases, and from time to time in the same case; whether profuse or scanty, it always exhibits the same oily, mucoid, slightly purulent appearance, and may stink abominably. With a very few exceptions it contains either the grey or the black grains already referred to; rarely similar bodies of a reddish or pink colour.

To the touch the swollen foot feels somewhat elastic, and does not readily pit on pressure. The sensibility of the skin is preserved. Although complained of in some instances, severe pain is rarely a prominent feature. The principal complaint is of inconvenience from the bulk and weight of the mass,

and, in advanced cases, of the uselessness of the limb for locomotion. In time the foot is no longer put to the ground, different unnatural styles of progression being adopted by different patients.

As the foot enlarges the leg atrophies from disuse; so that in the advanced disease an enormously enlarged and misshapen foot, flexed or extended, is attached to an attenuated leg consisting of little more than skin and bone. In some the tibia, or the bones of the forearm, as the case may be, become involved; in others the disease at first may be confined to a toe, or a finger, or other limited area. In a very few instances the seat of the disease is the knee, thigh, jaw, or neck. Unless the case be one of actinomycosis the internal organs are never specifically implicated, either primarily or secondarily. The lymphatic glands likewise, although they may be the subject of adenitis from secondary septic infection, are very rarely involved.

After ten or twenty years the patient dies, worn out by the continued drain, or carried off more suddenly by diarrhœa or other intercurrent disease.

Classification, etiology, and histology.—Formerly the tropical forms of mycetoma were classified according to the colour of the mycotic particles in the discharge. Thus we had the white or ochroid, the black or melanoid, and the red forms of mycetoma, the last being a very rare variety. Brumpt's investigations have made a classification more scientific than this crude clinical one possible; the latter, therefore, has to be abandoned.

This authority distinguishes eight different kinds of mycetoma, two of which are caused by species of *Discomyces*. Of the other six, two are certainly caused by species of *Aspergillus*. The remaining four are also probably due to species of aspergillus, but, in the absence of cultural evidence, he places them in two provisional groups: one of these, embracing the unpigmented septate species, he names *Indiella*; the other, the pigmented species, he calls *Madurella*. Moreover, he has shown that the fungi which give rise to mycetoma may present not only resisting

forms such as sclerotia and chlamydospores, but also characteristic spore apparatus (*Aspergillus nidulans*, *A. bouffardi*). The species are as follows :—

i. Actinomycotic Mycetoma

Caused by the ray-fungus, *Discomyces bovis* (Harz, 1877). Actinomycosis has a world-wide distribution and is a common disease of cattle. It occurs also in hogs. In men it may attack the extremities, giving rise to a tumour clinically indistinguishable from other kinds of mycetoma, or it may develop in the jaw, the tongue, lungs, liver, brain, and occasionally the primary lesion may be followed by metastases in all parts of the body.

The fungus of actinomycosis develops equally well in most tissues. It destroys bone by erosion and spares only nerves and tendons. The pus from the affected region contains small yellowish granules ("sulphur grains") of irregular shape, attaining at most 0·75 mm. in diameter. They are soft and consist of an inextricable felted mass of mycelia. The threads are radially arranged at the periphery of the grain, and their free extremity widens into a bulbous, club-like termination (10–20 μ long by 8–10 μ wide). These clubbed ends have been looked upon by several authors as forms of degeneration. Brumpt points out that they consist of young, active protoplasm, and holds that they are functionally hypertrophied while elaborating food for the colony. In old grains the clubs disappear, their protoplasm being utilized in the formation of spores.

This fungus gives rise to ramified sinuses which extend in all directions, opening at the surface by numerous vents. The sinuses are surrounded by a thick fibrous sheath of connective tissue. The centre of the largest tunnels is softened, the youngest grains being at the periphery surrounded by polynuclear cells and almost in contact with the sclerosed tissues which separate the cavities and sinuses.

The parasite has been successfully cultivated, and the disease has been inoculated both with the natural and the artificially grown organism.

Discomyces bovis lives saprophytically on certain plants. It has been found on the spikelets of cereals (*Hordeum murmium* L., *Phleum pratense* L., etc.), and is therefore probably inoculated through the skin or mucous membranes in the same way as the fungi which give rise to other kinds of mycetoma.

The diagnosis of the disease from tertiary syphilis and bone tuberculosis rests on the characteristic grains present in the pus.

The disease is progressive and of grave import. The treatment is largely surgical. In early cases iodide of potassium in doses of from 40 to 60 grains daily has proved advantageous and in some cases even curative.

ii. Vincent's White Mycetoma

Caused by *Discomyces maduræ* (Vincent, 1894). This kind of mycetoma is common and widely distributed. It has been observed in Algeria, in Abyssinia, in Somaliland, in the island of Cyprus, in India, in the Argentine Republic, and in Cuba.

It runs a slow course. Unlike *D. bovis* and other mycetoma-producing fungi, it does not destroy bone, and does not seem to act directly on the general health of the patient, though ultimately and indirectly it may bring about cachexia.

The grains formed by *Discomyces maduræ* vary in size from that of a pin's head to that of a pea. They are of a yellowish-white colour, present a mulberry-like surface, are soft and easily crushed. Their mode of growth is absolutely characteristic. The grain throws out from its periphery radiating filaments. Between these fungus threads are numerous lymphocytes (likewise arranged in radial series) embedded in an amorphous substance, probably arising from the destruction of lymphocytes, epithelial cells, and macrophages, on which the mycelium feeds. The crown of amorphous rays round the grain is typical. The grain is surrounded by numerous polynuclear leucocytes. Having attained from 1 to 1·5 mm. diameter, the grain projects small shoots which become detached from the parent grain, enlarge, and reproduce the characteristic radial structure. Other grains form also, and, after a time, the typical large mulberry granule is formed, the central grains degenerating. The grains are found in cavities surrounded by inflammatory connective tissue permeated by polynuclear cells and occasionally giant cells.

iii. Nicolle's White Mycetoma

Caused by *Aspergillus nidulans* (Eidam, 1883). So far only one case has been observed, in Tunis, but probably it occurs in many places, the parasite *Aspergillus nidulans* being widely distributed. The grains formed by this fungus may also attain the size of a pea, but they differ from those of *Discomyces maduræ*, inasmuch as they are more or less spherical and present a smooth surface.

In this form of mycetoma the bones are attacked and destroyed.

iv. Bouffard's Black Mycetoma

Caused by *Aspergillus bouffardi* (Brumpt, 1906). This form was discovered by Bouffard at Djibouti, Somaliland. Lewis seems to have met a similar case in India; a third case, probably also belonging to this species, was described by Bovo in Italy.

The grains are quite characteristic. They are black in colour and vary in size from a pin's head to that of No. 1 shot. They present a mulberry-like surface which is smooth and glossy. They are somewhat elastic, but break when pressed. Their structure is remarkable. It consists of a coiled-up mass. Maceration in water for about twenty-four hours causes the grain to unfold. Sections show that the grain is composed of a

densely felted mycelium of a silvery-white colour, with a peripheral zone of irregularly moniliform threads with terminal chlamydospores cemented together by a dark brown interstitial substance.

The grains are found in the cellular tissue, always singly and within small cavities. Each grain is surrounded by enormous giant cells, and by epithelioid cells of all sizes, and is enclosed in a characteristic shell of connective tissue.

This kind of mycetoma appears to be more amenable to treatment. Bouffard's and Bovo's cases were radically cured by curettage. In Bovo's case a secondary extension to the groin lymphatics of the affected side had suggested the diagnosis of melano-sarcoma.

v. Classic Black Mycetoma

Caused by *Madurella mycetomi* (Laveran, 1902). This mycetoma has a very wide distribution. It has been observed in Italy, in Africa (Senegal, French Soudan), and in India.

The grain formed by *Madurella mycetomi* is dark brown or black in colour. It measures 1 to 2 mm. in diameter, is hard and brittle; its surface is irregular and frequently presents pointed eminences which differentiate it from the larger and smooth grains of *Aspergillus bouffardi*. The grain is composed of white threads, always over 1 μ in diameter and attaining at times 8 to 10 μ, which secrete a dark brown substance that cements them together. The grain is first surrounded by giant cells, epithelioid cells, and numerous polynuclear cells, and shows numerous chlamydospores at the periphery. Then a thick capsule of fibrous connective tissue forms round it. This puts an end to the vegetation of the fungus, which passes into a resting stage and is converted into sclerotia, in which form it is eliminated. This was shown by Carter as early as 1860. The grains form rapidly within the tissues. Brumpt reports a case in which they were eliminated in large numbers one month after the commencement of the disease.

Each grain may become the centre of an active colony, which continues to extend, destroying the surrounding tissues, until arrested by a barrier of sclerosed tissue. Thus large tumours may be formed. In very old grains the mycelium presents cavities filled with numerous chlamydospores. Sometimes, on account of unfavourable conditions, certain lobes of the fungus separate from the rest of the colony and become independent grains. This mode of vegetation, characteristic of the species, gives to the lesions a typical rosette-like appearance.

vi. Brumpt's White Mycetoma

Caused by *Indiella mansoni* (Brumpt, 1906). This form was described from a specimen of Indian origin in the museum of the London School of Tropical Medicine.

The grains peculiar to this form are hard, white, and very small, varying in size between $\frac{1}{8}$ and $\frac{1}{4}$ mm., and having

a lenticular shape. Some are bean-shaped and flat. To study their structure it is necessary to boil them first in a solution of caustic potash. The hyphal threads are large and closely set, but without any cementing substance between them. The periphery of the grain contains numerous large chlamydospores with thick wall and full of protoplasm.

The grains of *Indiella mansoni* are always numerous within the inflammatory tissue. The latter is brownish and is not surrounded by a well-marked sheath of connective tissue as in other mycetomas. It contains numerous polynuclear cells, a few lymphocytes, and some macrophages.

vii. Reynier's White Mycetoma

Caused by *Indiella reynieri*, Brumpt, 1906. This form was found in Paris by Reynier.

The grains may attain 1 mm. in diameter; they are soft, white, and consist of a coiled-up strand, which gives them a peculiar appearance resembling the excrement of earthworms. They are made up of a dense felting of hyphal threads, the peripheral branches of which usually terminate in chlamydospores divided into two or three compartments. The hyphæ are bound by a scanty cement, which is easily dissolved out by boiling in caustic potash.

viii. Bouffard's White Mycetoma

Caused by *Indiella somaliensis*, Brumpt, 1906. This form is perhaps even more common in India than Vincent's white mycetoma. Bouffard has found it twice in Somaliland.

Indiella somaliensis is a most destructive fungus. In a foot examined by Brumpt all the muscles, tendons, and bones had been replaced by sclerosed tissues more or less homogeneous and presenting numerous sinuses full of yellowish grains clustered together like fish-roe, and many small inflammatory nodules containing one or more grains.

The grains vary in colour from white to reddish yellow; they are small, smooth, and attain on an average about 1 mm. in diameter. They are spherical when single, but polyhedral from reciprocal pressure when clustered in masses. The parasite in its earliest stage is always found in a giant cell, showing as an irregular mass which stains more deeply than the enclosing cell. Usually several infected cells coalesce; the grain which results is surrounded by an amorphous layer produced by the destruction of the elements which form its substratum. The grains are not enclosed within nodules, as is the rule in certain mycetomas, but spread exactly like those of actinomycosis.

In the amorphous zone of cellular detritus Brumpt found a discomyces which seems to live symbiotically with *Indiella somaliensis*. In attempts at culture Bouffard found that this discomyces was the only organism that grew. Other investigators—Boyce, Vincent, Musgrave and Clegg, etc.—have cultivated a streptothrix from the white variety, differing from the

actinomyces in producing no pigment and forming white raised colonies on agar. Probably there are several conditions in actinomycosis, as in mycetoma, bearing a general resemblance to each other, but differing slightly according as they are produced by different species of streptothrix.

Morbid anatomy.—On cutting into a mycetomatous foot or hand the knife passes readily through the mass, exposing a section with an oily, greasy surface, in which the anatomical elements in many places are unrecognizable, being, as it were, fused together, forming a pale, greyish-yellow mass. The bones in parts have entirely disappeared; where their remains can still be made out the cancellated structure is very friable, thinned, opened out, and infiltrated with oleaginous material. Of all the structures the tendons and fasciæ seem to be the most resistant.

The most remarkable feature revealed by section is a network of sinuses and communicating cyst-like cavities of various dimensions, from a mere speck to a cavity an inch or more in diameter. Sinuses and cysts are occupied by a material unlike anything else in human morbid anatomy. In the black varieties of mycetoma this material consists of a black or dark brown, firm, friable substance which, in many places, stuffs the sinuses and cysts; manifestly it is from this that the black particles in the discharge are derived. In the white varieties the sinuses and cysts are also more or less stuffed with a white or yellowish roe-like substance, evidently an aggregation of particles identical with those escaping in the corresponding discharge. The black substance, which can be readily turned out, is moulded into truffle-like masses ranging in size from a mere grain to a small apple, according to the capacity of the cysts or sinuses containing it. The roe-like particles in the white varieties are held together by a softer, cheesy-looking material. The sinuses and cysts occupy the bones, muscles, or fasciæ indiscriminately; they are found principally in the fat and the connective tissue. They are lined with a smooth membrane, adherent when in the soft tissues, but capable of being enucleated when in the bones. Some of the cysts do not communicate with sinuses; most of them, however,

do so, and with each other, opening on the surface of the skin at the mammillated fistulæ already referred to. In the very rare red variety the colour of the accretions is red or pink.

Under the microscope the mycotic elements can be readily recognized in the concretions. In microscopic sections of the tissues evidences of extensive degenerative changes, the result of a chronic inflammatory process, can be made out. An important feature as bearing on the pathology of the disease, and one which was long ago described by Lewis and Cunningham, has been insisted on more recently by Cunningham, namely, a sort of arteritis obliterans or extensive proliferation of the endothelium of the arteries and, according to Vincent, a thickening of the adventitia of the vessels as well as of the capillaries in the more affected areas.

Mode of entrance of the fungus.—Little is known on this point. It is conjectured that the fungi live as parasites on certain plants, and that they may penetrate the tissues of man through a wound in the skin. The peculiar endemicity and geographical distribution of the disease, and the facts of its occurring almost invariably on the feet or hands, and principally in bare-footed agriculturists, favour this view.

Treatment.—The only effective treatment, in the case of implication of a considerable part of the foot or hand, is amputation. This must be performed well above the seat of the disease; for it must be borne in mind that the long bones may be implicated as well as the small bones, and that unless the entire disease be removed it will recur in the stump. Complete removal is not followed by relapse. If a toe, or a small portion of the foot or hand, is alone involved, this may be excised with success. Potassium iodide has been found to be beneficial in certain forms.

Dhobie's Itch

In view of the recent researches of Sabouraud and others on the ringworms of Europe, there can be little doubt that the ringworms of warm countries are attributable to a large variety of fungus forms, probably

many of them derived from the lower animals. Although, in a general way, we are familiar enough with the clinical features of these ringworms, their specific germs have not as yet been very closely studied. By the lay public all epiphytic skin diseases, more especially all forms of intertrigo, are spoken of as dhobie's (washerman's) itch, in the belief, probably not very well founded, that they are contracted from clothes which have been contaminated by the washerman. There are many sources of ringworm infection in warm climates besides the much maligned dhobie.

In the tropics, native children often exhibit dry, scurfy patches of ringworm on the scalp; and the skin of the trunk and limbs of adults is not infrequently affected with red, slightly raised, itching rings, or segments of rings, of trichophyton infection. Sometimes these rings enclose areas many inches in diameter.

Pityriasis versicolor is also very common in the tropics. It is the usual cause of the pale, fawn-coloured, slightly scurfy patches so frequently a feature on the dark-skinned bodies of natives. On the dark-pigmented skins of negroes, Indians, and dark-complexioned Chinese, the patch of pityriasis—contrary to what obtains in Europeans and light-skinned Chinese—is usually paler than the healthy integument surrounding it. The pigment in the fungus and the profuse growth of the latter conceal, as a coat of paint might, the dark underlying natural pigment of the skin, which, moreover, in certain cases, seems to be affected (either increased or decreased) by the action of the fungus. Castellani has recently studied the several forms of mycotic pityriasis as they occur in Ceylon. He recognizes three forms: *Pityriasis versicolor flava*, produced by *Microsporon tropicum*, a fungus having a thick irregular constricted mycelium; *Pityriasis versicolor alba*, produced by a very minute fungus with straight, short mycelia, *Microsporon macfadyeni*; and *Pityriasis versicolor nigra*—a variety I had described many years ago as occurring in South China—produced by *Microsporon mansoni*, which contains much dark

pigment in the mycelial tubes, and which on culture in maltose agar produces black hemispherical colonies.

The expression *dhobie's itch*, although applied to any itching, ringworm-like affection of any part of the skin, most commonly refers to some form of epiphytic disease of the crutch or axilla. There are at least three species of vegetable or bacterial parasites which in the tropics are prone to attack these situations—namely, the trichophytons or ordinary body ringworms, the *Microsporon minutissimum* of erythrasma, and the germ of the disease I have described under the name pemphigus contagiosus.

The suffering to which some of the forms of dhobie's itch give rise is often severe. In hot, damp weather especially, the germs proliferate actively, producing, it may be, smart dermatitis. The excessive irritation thus set up leads to scratching and, very likely, from secondary bacterial invasion, to boils or small abscesses. The crutch, or axillæ, or both are sometimes rendered so raw and tender that the patient may be unable to walk or even to dress. The irritation and itching are usually worse at night, and may keep the patient awake for hours. Even in the absence of treatment, when the cold season comes round the dermatitis and irritation subside spontaneously. The affected parts then become dry, pigmented, and scurfy, and the fungus remains quiescent until the return of the next hot weather.

Diagnosis.—The diagnosis of mycotic dermatitis is usually easily made. The festooned margin is almost conclusive. In the case of pemphigus contagiosus the characteristic blebs, the smooth, raw, or glazed surfaces, and undermined epidermic rings are usually very apparent and render diagnosis easy. When doubt exists, recourse to the microscope may be necessary; but, owing to the inflamed condition of the parts, there may be much difficulty in finding fungus elements even when the case is certainly epiphytic. A negative result is, therefore, not always conclusive against ringworm.

I am convinced that many cases of dhobie's itch are produced by *Microsporon minutissimum*, and that

they are really inflamed erythrasma and not trichophyton ringworm. During cold weather one often sees, on the site of what, during the summer, had been a troublesome dhobie's itch, a brownish furfuraceous discoloration of the crutch or axilla. The same appearance I have remarked in Europe in Europeans who had suffered from dhobie's itch in the East, and on examining scrapings from the parts have found *M. minutissimum* in abundance. It would seem, therefore, that during the heat and moisture of a tropical summer this generally very unirritating parasite becomes more active and excites dermatitis. The same may sometimes be seen in pityriasis versicolor. I believe that those cases of *Microsporon—furfur* and *minutissimum*—dhobie's itch are more easily cured than the trichophyton varieties.

Treatment.—After a thorough use of soap and water, the application of Vlemingkx's solution of sulphuret of calcium (1 oz. quicklime, 2 oz. precipitated sulphur, 15 oz. water, boiled together in an earthenware vessel till reduced to 10 oz.; decant the clear sherry-coloured fluid after subsidence) every night for three or four times generally brings about a rapid cure. If the parts are inflamed and tender the solution should be diluted to half or one-quarter strength for the first two applications. A preliminary soothing treatment by lead lotion, or an ichthyol or hazeline ointment is desirable in such cases. A tincture of the leaves of *Cassia alata* painted on, or the crushed leaves themselves well rubbed in, are equally successful. If these fail, chrysophanic acid ointment, 20 gr. to the ounce of vaseline, rubbed in twice a day till a slight erythema shows at the edge of the diseased patch, is almost invariably successful. When prescribing chrysophanic acid the physician must be careful to inform the patient of its staining effect on clothes; to warn him to stop its use so soon as the erythematous ring shows; and to be careful not to apply the ointment to the face. A writer in the *Indian Med. Gaz.* (Jan., 1898) strongly recommends the application of glacial acetic acid. It cures, he affirms, with, at most, two applications. The smarting

Tinea imbricata.

PLATE XV.

its use entails is relieved by laying a lump of ice in a handkerchief on the part. Castellani and Chalmers recommend an ointment of resorcin ʒi, salicylic acid gr. x, lanoline, vaseline, āā ʒiv, to be applied twice a day. For the ringworms of the thick-skinned natives linimentum iodi freely applied, and of double strength, is the best, and a most efficient remedy.

Prophylaxis.—The various forms of crutch dhobie's itch may be avoided by wearing next the skin short cotton bathing-drawers and changing them daily; at the same time powdering, after the daily bath, the axillæ and crutch with equal parts of boric acid, oxide of zinc, and starch.

TINEA IMBRICATA (Plate XV.)

Definition.—A form of body ringworm, until lately peculiar to certain Eastern oceanic tropical climates, produced by a trichophyton (lepidophyton, Tribondeau), and characterized by a concentric arrangement of closely set rings of scaling epidermis.

Geographical distribution. — This peculiar form of epiphytic disease is strictly confined to warm climates. It is principally met with in the Eastern Archipelago and in the islands of the South Pacific, although it has been found to extend westward as far as Burma, and northward as far as Foochow and Formosa on the coast of China. In many of the islands of the South Pacific it affects a large proportion of the inhabitants; in some islands quite one-half. There is good reason to believe that its area of distribution is gradually extending. Thus Turner and Königer tell us that it was formerly unknown in Samoa and Bowditch Islands, where it is now very prevalent. Daniels informs me that it was introduced for the first time into Fiji by some Solomon Islanders in 1870; by 1872 it had become general among the Fijians. It was recently introduced into Tahiti, and rapidly spread there among the natives. We have no accounts of such a disease in Africa. Recently it has been described by Paranhos and Leme as occurring in the interior of Brazil. Once

introduced, it spreads very rapidly in countries with a damp, equable climate and a temperature of 80° to 90° F. Very high or very low temperatures and a dry atmosphere are inimical to its extension.

Symptoms.—Tinea imbricata is easily recognized. At first it may be confined to one or two spots on the surface of the body; usually, in a short time, it comes to occupy a very large area. It does not generally affect the soles and palms, although it may do so; nor is the scalp a favourite site. Baker, confirmed by Tribondeau, remarks that it avoids the crutch, the axillæ, and, contrary to Castellani's experience, the nails. With these exceptions it may, and commonly does, sweep over and keep its hold on nearly the entire surface of the body; so that after a year or two a large part of the skin is covered with the dry, tissue-paper-like scales, arranged in more or less confused systems of concentric parallel lines, absolutely characteristic of the disease.

An inoculation experiment readily explains the production of the scales, their concentric parallel arrangement, and the mode of extension of the patches. About ten days after the successful inoculation of a healthy skin with tinea imbricata, the epidermis at the seat of inoculation is seen to be very slightly raised and to have a brownish tinge. Presently the centre of this brownish patch—perhaps a quarter of an inch in diameter—gives way and a ring of scaling epidermis, attached at the periphery, but free, ragged, and slightly elevated towards the centre of the spot, is formed. In a few days this ring of epidermis has extended so as to include a larger area. A second brown spot then appears at the site of the first brown spot and in the centre of the primary scaling, expanding ring. This second spot, in its turn, gives way, producing a second and similar scaling ring, which also expands, following the first ring in its extension. Later a third and fourth ring form in the same way; and so on, until a large area of skin is covered with one or more systems of concentric parallel scaling rings, which follow each other over the surface of the body

like the concentric ripples produced by a stone falling into a pool of water.

The scales, if not broken by rubbing, may attain considerable length and breadth; but, of course, their dimensions are in a measure determined by the amount of friction they are subjected to. Usually they are largest between the shoulders—that is, where the patient has a difficulty in scratching himself. The lines of scales are from $\frac{1}{8}$–$\frac{1}{2}$ in. apart. The hair of the scalp is not injured.

The fungus.—On detaching a scale and placing it under the microscope, after moistening with liquor potassæ, a trichophyton-like fungus can be seen in enormous profusion. The parasite evidently lies between epidermis and rete, and by its abundance causes the former to peel up. As the fungus does not die out in the skin travelled over, it burrows under the young epithelium almost as soon as the latter is reproduced. Hence the peculiar concentric scaling and the persistency of the disease throughout the area involved. When the scales are washed off by the vigorous use of soft soap and hot water, the surface of the skin is seen to be covered with parallel lines of a brownish colour—evidently the slightly pigmented fungus proliferating and advancing under the young epidermis. Tribondeau, on the evidence of finding fructification in one of his attempts at culture, pronounces the fungus to be a lepidophyton and not a trichophyton. Castellani has succeeded in cultivating the true parasite; this he has proved by the reproduction of the characteristic skin lesions by inoculation of his cultures. He considers that in tinea imbricata we have to deal with at least two distinct species, which he has named *Endermophyton concentricum* and *E. indicum.* Castellani obtained cultures by immersing imbricata scales in alcohol for five to ten minutes and then placing them in tubes of glucose broth—one scale in each tube. Usually most of the tubes become contaminated with bacteria, but a few remain clear; in the latter, in five to ten days, fine white threads may be seen spreading from the scales. In three to four weeks, if portions of this are

transferred to solid agar media, characteristic cultures can be obtained, and are inoculable into the human subject.

Diagnosis.—From ordinary ringworm tinea imbricata is easily distinguished by the absence of marked inflammation or congestion of the rings, by the abundance of the fungus, by the large size of the scales, by the concentric arrangement of the many rings or systems of rings, by the non-implication of the hair, and, according to Baker, by the avoidance of crutch and axillæ. From ichthyosis it is distinguished by the concentric arrangement of the scaling, by the peripheral attachment of the scales, and by the presence of abundant fungus elements.

Treatment.—The best treatment for tinea imbricata in natives is the free application of strong linimentum iodi. Limited patches might be treated with chrysophanic acid ointment (20 gr. to the ounce) or by the inrubbing of bruised *Cassia alata* leaves. Paranhos and Læme recommend a tepid alkaline bath of sodium bicarbonate (1 kilogramme to 20 litres of water), followed by the application of ocalia perdiceps 50 grm., glacial acetic acid 15 grm., macerated for two days in glycerinated water (10 per cent.) 985 grm., and then filtered. Sulphur ointment, or sulphur fumes, act very slowly and unsatisfactorily. Clothes should be boiled or burned.

Prophylaxis.—Daniels informs me that tinea imbricata is a comparatively rare disease in Tonga. This circumstance the natives attribute to their custom of oiling the body. Daniels remarks that of late years, since the Fijians adopted the same practice, the disease has become somewhat less prevalent among them. Personal cleanliness, and the immediate and active treatment of any scaling spot, should be carefully practised in the endemic countries.

In Tahiti the use of chrysophanic acid is now general among the natives; as a consequence the disease is not so prevalent there as it was only a few years ago.

PINTA

Definition.—An epiphytic disease characterized by peculiar pigmented patches on the skin.

Geographical distribution.—In certain districts in tropical America, especially along the river banks in Mexico, Central America, Venezuela, Colombia, Bolivia, and one or two places in Peru, Chile, and Brazil—the district between the Juciparana and the Santo Antonio rivers (Magalhães, private letter)—there occurs an epiphytic skin disease characterized by peculiar red, or blue, or black, or white piebald spotting of the skin of a part, or of the whole, of the body. The patient emits an offensive odour, sometimes compared to that of a mangy dog or of dirty linen. Desquamation and itching of the patches are also features of the disease. It entails no constitutional disturbance and no danger to life. Like other epiphytic diseases, want of personal cleanliness has a great deal to do with the prevalence of pinta in the districts mentioned, for it is rare in cleanly whites or well-to-do negroes; the dirty Indians and the poor half-castes are those most frequently affected. In some districts it occurs in nearly a tenth part of the inhabitants, in others nearly the entire population is affected. Lately a somewhat similar disease has been seen in North Africa,* in Egypt, and possibly in the Malay peninsula.

Symptoms.—Pinta commences at one or two points, the rest of the surface of the skin becoming infected in turn by extension or by auto-contagion.

* It is difficult from his description to determine the exact nature of the disease alluded to by Legrain. It commences with pronounced fever lasting for one week, and is followed by malaise persisting for several weeks. This is followed by itching and, by and by, by furfuraceous desquamation of the itching parts and gradually developed achromia. He positively affirms that the disease is not ordinary vitiligo. He also says he has seen in Tripoli a coloured skin affection with the clinical features of true pinta occurring in little epidemics in particular houses. The results of microscopical examinations of scrapings of the affected skin were negative. Possibly this is the disease referred to in the *Journ. of Trop. Med.*, Nov., 1899, by Sandwith, as having been seen by him in Egypt. Varieties of pityriasis versicolor, such as Castellani has described in Ceylon, may have been mistaken sometimes for true pinta.

At first the hands, or face, or some other exposed parts, are attacked. The original patch may be white, red, blue, or black. It gradually increases in size, becoming scurfy and itchy, particularly when the surface is warm. As the patches spread they assume a variety of shapes. Fresh spots appear in the neighbourhood of the parent spots, into which, in course of time, they tend to merge; so that ultimately large patches of discoloured skin are formed. The palms of the hands and the soles of the feet are not attacked. On the scalp becoming affected the hair turns white and thin and ultimately falls out. When fully developed, the disease produces a very grotesque appearance. It is probable that the white patches in a proportion of cases are not epiphytic, as they neither itch nor desquamate; very likely they are ordinary leucodermia, possibly brought about by disturbance of the natural pigmentation by a parasite which had subsequently died out. Sensation and the glandular functions of the skin are not affected. In consequence of the scratching, the implicated parts may become cracked or ulcerated.

Two types of the disease have been named—the superficial epidermic and the deep epidermic; the former being represented by black and blue patches which spread rapidly; the latter including the red and white patches, apparently involving the rete and deeper layers of the epidermis, spreading more slowly, and, at the same time, being more difficult to cure. The various forms and colours may concur in the same individual; but a given patch, once established, does not change colour.

Pinta is contagious. It attacks both sexes and any age. Unless properly treated it may last for years.

Pathology.—If one of the scales is moistened with liquor potassæ and placed under the microscope, black spores and a white, highly refracting mycelium are found. The spores are round or oval, measuring 8 μ to 12 μ in diameter. Abundant pigment is seen floating in a yellowish fluid in the interior of the spore. The mycelial filaments are short, non-branching, tapering from a broad base to a blunt point by

which each filament is attached to a single spore, like the stalk to a cherry. The mycelium measures from 18 μ to 20 μ in length by 2 μ in breadth. The differences in the colour of the patches probably depend on differences in the pigmentation, or kind, of the fungus. Such is Gastambide's description of the parasite—a description which, to some extent, is borne out by Osborne Browne.

Montoya y Florez has published an elaborate and careful description of the disease and of the various mycotic growths he found in the several varieties of pinta which he studied. He says that he has never seen a fungus answering to Gastambide's description. On placing the scales moistened with liquor potassæ under the microscope, long dichotomous filaments, generally very fine and cylindrical, in certain conditions granular and beaded, are seen. In places this mycelium forms a dense network. Here and there veritable ropes of mycelium are visible, or broad, short filaments with fructification characteristic of the particular variety of the disease may be detected (Fig. 192). He has succeeded in cultivating the various fungi, which apparently belong to a plurality of genera—*Penicillium*, *Aspergillus*, *Monilia*.

Diagnosis.—This disease is readily diagnosed from leprosy by the absence of anæsthesia in the patches, and by the colour of the spots; from erythrasma, from ringworm, and from pityriasis versicolor by the colour, and by the microscopic characters of the fungus.

Treatment.—Chrysophanic acid, preparations of sulphur, strong liniment of iodine, and other epiphyticides are indicated. Cleanliness and the destruction of old clothes are indispensable.

Piedra

This peculiar disease of the hair is very common in certain districts of Colombia, South America. So far as is known, it is confined to the inhabitants of that country, of whom a considerable proportion, both male and female, and apparently belonging to all the races represented there, are affected.

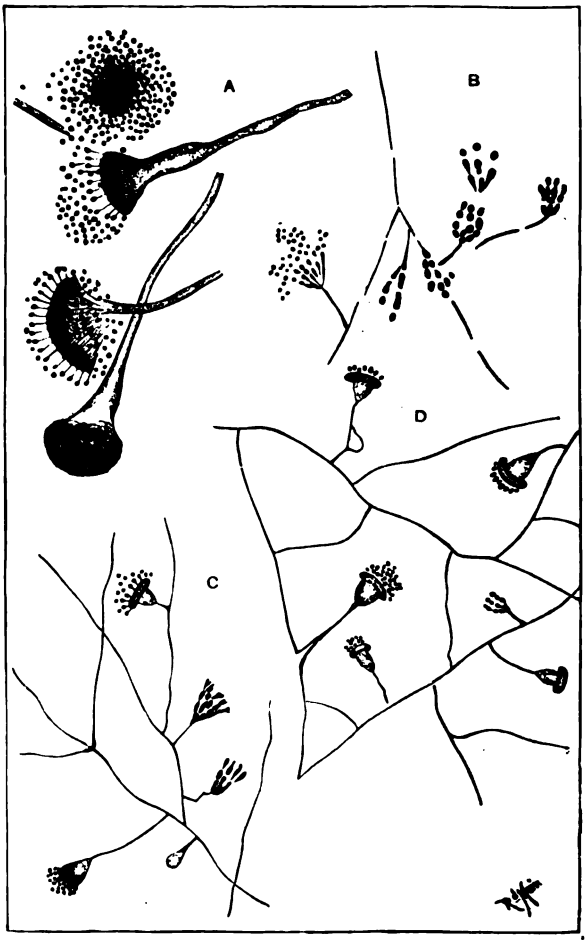


Fig. 192.—Fructification of cryptogamic epiphytes in pinta. (*After Montoya y Florez.*)

A, Red pinta ; B, dark-violet pinta ; C, grey-violet pinta ; D, blue pinta.

According to Juhel-Rénoy, whose observations practically coincide with the earlier accounts by Desenne, Cheadle, Morris and others, the hairs of the affected scalp are dotted over at irregular intervals with numerous—twenty-three in a hair 60 cm. in length — minute, gritty nodosities. These, barely visible to the naked eye, are distinctly perceptible to the touch when the hair is drawn between finger and thumb. The affected hairs are bent and twisted, and tend to produce matting and knotting. The little nodosities, which, though very firm, are not so hard as the name piedra (a stone) would indicate, being easily cut through with a sharp knife or scissors, are paler than the hair which they surround, or partly surround, like a sheath. When a comb is drawn through the hair a sort of crepitation is produced, doubtless by the friction against the hard particles.

Under the microscope these excrescences are found to consist of a number of spore-like bodies, easily made apparent by soaking the hair in liquor potassæ after washing in ether. The spores (which are twice the size of trichophyton spores and remarkably refringent) from mutual pressure are polyhedral, and together form a sort of tessellated mosaic, the elements of which seem to be held together by a greenish soluble cement in which a number of minute bacteria-like rods are incorporated. The shaft of the hair is not eroded or affected in any way; it can be seen intact through the encrusting fungus.

Piedra is supposed by some to be induced by the mucilaginous hair applications in vogue among the Colombians. Although Juhel-Rénoy has given to it the name "trichomycose nodulaire," it must not be confounded with the trichomycosis nodosa of Paterson (the leptothrix of Wilson), which is quite a different affection and common enough on the axillary, scrotal, and face hair in Europe and elsewhere. Neither must it be confounded with trichorexis nodosa, a non-parasitic disease of the hair-shaft, which is split up at different points into brush-like bundles of fibres

and is thus easily fractured; nor with moniliform hair (monilethrix, Crocker), a congenital, hereditary, and also non-parasitic disease.

Treatment.—Cleanliness, the free use of soap, and the application of some epiphyticide should suffice for cure. Should such means fail, doubtless shaving the scalp would be effectual.

4. CAUSED BY ANIMALS

THE CHIGGER OR SAND FLEA (DERMATOPHILUS PENETRANS)

This insect, formerly confined to the tropical parts of America (30° N. to 30° S.) and to the West Indies, appeared on the West Coast of Africa for the first

Fig. 193.—Chigger (Dermatophilus penetrans). (*Blanchard.*)

time about the year 1872. Since that date it has spread all over the tropical parts of that continent and even to some of the adjacent islands—Madagascar for example. As a cause of suffering, invaliding, and indirectly of death, it is an insect of some importance. It is now extremely prevalent on the East Coast of Africa, and is causing a large amount of invaliding amongst the Indian coolies there, by whom it has been introduced into India.

The chigger (Fig. 193) is not unlike the common flea (*Pulex irritans*) both in appearance and, with one exception, in habit. It is somewhat smaller in size—1 mm., the head being proportionately larger and the abdomen deeper than in the latter insect. In colour it is red or reddish brown. Like the

flea, its favourite haunt is dry, sandy soil, the dust and ashes in badly kept native huts, the stables of cattle, poultry pens, and the like. It greedily attacks all warm-blooded animals, including birds and man. Until impregnated, the female, like the male, is free, feeding intermittently as opportunity offers. So soon as she becomes impregnated she avails herself of the first animal she encounters to burrow diagonally into its skin, where, being well nourished by the blood, she proceeds to ovulation. By the end of this process her abdomen, in consequence of the growth of the eggs it contains, has attained the size of a small pea (Fig. 194). The first anterior and the two posterior segments do not participate in the enlargement, the latter acting as a plug to the little hole made by the animal when she entered the skin. When the ova are mature they are expelled and fall on the ground. In a short time a thirteen-ringed larva is hatched out from each egg. This larva presently encloses itself in a cocoon, from which, in eight or ten days, the perfect insect emerges.

Fig. 194.—Chigger: impregnated female. (*Blanchard.*)

During her gestation the chigger causes a considerable amount of irritation. In consequence of this, pus forms around her distended abdomen, which now raises the inflamed integument into a pea-like elevation. After the eggs are laid (according to some, before this process) the superjacent skin ulcerates and the chigger is expelled, leaving a small sore which, if infected by any pathogenic micro-organism, as the bacterium of phagedæna or of tetanus, may lead to grave consequences.

Naturally, being nearest the ground, the feet are the parts most commonly infested by chiggers. The soles of the feet (Fig. 195), the skin between the toes, and that at the roots of the nails are favourite situations. Other parts of the body are by no means exempt; the scrotum, penis, the skin around the anus, the thighs, and even the hands (Fig. 196) and face, are often attacked.

Usually only one or two chiggers are found at a time; occasionally they are present in hundreds, the little pits left after their extraction being sometimes so closely set that parts of the surface may look like a honeycomb.

Fig. 195.—Chiggers in sole of foot.
(*From a photograph by Daniels.*)

Treatment.—In chigger regions, houses, particularly the ground floors, must be frequently swept and accumulation of dust and débris be prevented. The housing of cattle and poultry must be similarly attended to. The floors should be sprinkled often with carbolic water, pyrethrum powder, or similar insecticide. Walking barefooted must be avoided. Bathing

must be practised daily, and any chiggers that may have fastened themselves on the skin at once removed, They may be killed by pricking them with a needle. or by the application of chloroform, turpentine, mercurial ointment, or similar means, after which they are expelled by ulceration. The best treatment, however, is not to wait for ulceration, but to enlarge the

Fig. 196.—Chigger lesions of hands and feet.
(*From a photograph by Daniels.*)

orifice of entrance with a sharp, clean needle and neatly to enucleate the insect entire. Some native women, from long practice, are experts at this little operation. The part must be carefully dressed and protected until healed. Europeans living in an endemic district should wear high boots. A daily inspection of the feet, especially under the nails, is advisable. Should any black dot be discovered, the chigger should at once be removed.

MYIASIS

THE SCREWWORM (*Chrysomyia macellaria*)

This is the larva of a dipterous insect (Fig. 197) common in certain parts (especially the tropics) of America, from Canada to Patagonia. The insect (9-10 mm. long) lays a mass

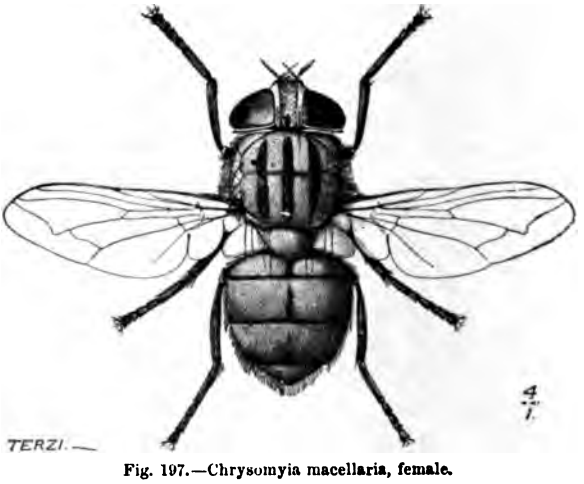


Fig. 197.—Chrysomyia macellaria, female.

of three or four hundred eggs on the surface of wounds, and in the ears and nasal fossæ (Fig. 199) of persons sleeping in the open air, especially of those having offensive discharges, which attract the fly. From these eggs the larvæ are hatched in a few

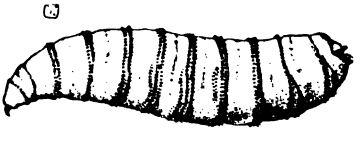


Fig. 198.—Chrysomyia macellaria, larva.

hours. The larvæ (Fig. 198) are white, about three-quarters of an inch in length, and formed of twelve segments carrying circles of minute spirally arranged spines which give the creature a screw-like appearance; hence the vulgar name. They burrow in the tissues, devouring the mucous membrane, muscles, cartilages, periosteum, and even the bones, thereby

causing terrible sores, and not infrequently—particularly when they attack the ear or nasal fossæ, by penetrating to the brain—death. Of 13 cases collected by Laboulbène 9 proved fatal; of 31 collected by Maillard 21 died.

If treated properly and in time by injections of chloroform, carbolic acid, turpentine, infusion of pyrethrum, and similar

Fig. 199.—Native with Chrysomyia macellaria in nostrils and frontal sinuses; early stage. (*From a photograph by Daniels.*)

substances, the patient may be saved; neglected, he will most probably die. If necessary the frontal sinuses, the antrum, and other bony cavities must be opened to secure the expulsion of the larvæ.

In countries where this pest occurs bloody and offensive discharges from the nostrils should be carefully investigated, and, if found to be caused by the screwworm, vigorously treated.

Ver Macaque (*Dermatobia cyaniventris*)

This is the larva of an American fly (Fig. 200) the identity of which, until it was studied by Blanchard, was doubtful.

At an early stage the larva has the appearance represented by Fig. 201; at a later stage, that represented by Fig. 202.

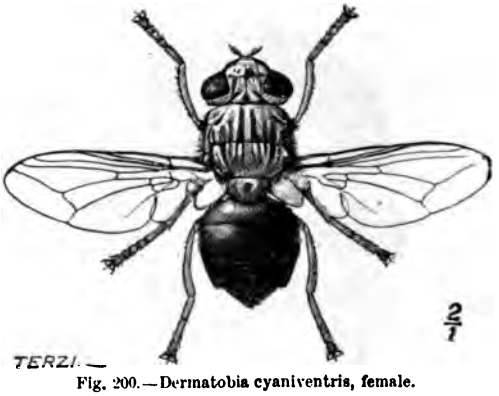


Fig. 200.—Dermatobia cyaniventris, female.

The former stage of the larva is called *ver macaque;* the latter, much larger, *torcel* or *berne*. At one time these two larval stages of the same insect were erroneously supposed to belong to different species.

Dermatobia cyaniventris measures from 14 to 16 mm. in

Fig. 201. — Dermatobia cyaniventris, larva, early stage. (*Blanchard.*)

Fig. 202.—Dermatobia cyaniventris, larva, later stage. (*After Brauer.*)

length; it has a yellow head with very prominent brown eyes; the thorax is of a greyish colour, the abdomen of a dark metallic blue. It is widely distributed throughout tropical America, being especially common near wooded lands. It

attacks the most diverse animals. Commonly it is found in cattle, pigs, and dogs, but it occurs in the agouti, in the jaguar, in various monkeys, and in birds. It is rare in the mule, and writers have commented upon its absence from the horse. In man it has been reported from various regions of the body, namely, head, arm, back, abdomen, scrotum, buttocks, thigh, axilla. Its presence is accompanied by excruciating pains, especially at those times when the larva is moving.

It is supposed that when hatched out the larvæ penetrate the skin and produce an inflamed swelling about the aperture of entrance, from which a seropurulent fluid, containing the black fæces of the larva, exudes. Possibly it may reach the subcutaneous tissue by migration from the alimentary canal, as is the case in the allied European species, *Hypoderma bovis* (warble fly). Depied says that he has twice encountered this larva in the scalp of Tonquinese.

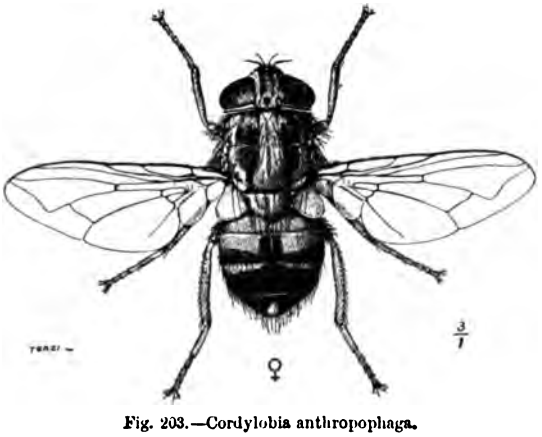


Fig. 203.—Cordylobia anthropophaga.

Ver du Cayor (*Cordylobia anthropophaga*)

Synonym.—*Ochromyia anthropophaga.*

Cordylobia anthropophaga (Fig. 203) measures from 8·5 to 11·5 mm. in length. It is of a yellowish-grey colour, with black spots on the abdomen. It was first reported from Cayor, Senegambia, but it is probably widely distributed in tropical Africa. The larva (Fig. 204) burrows into the skin of man and beast, and produces a small inflamed swelling, from which it emerges in from six to seven days.

In Africa, and in many other parts of the tropical world, similar anthropophagous larvæ, which, however, have not yet been satisfactorily identified, are frequently encountered.

According to Grünberg all these larvæ belong to one species—*Cordylobia anthropophaga* (Fig. 203); on the other hand, Gedoelst distinguishes four different species—*Ochromyia anthropophaga*, *Bengalia depressa* (widely distributed), *Cordylobia anthropo-*

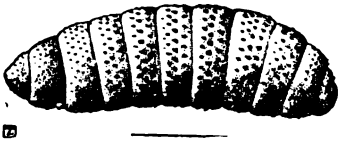


Fig. 204.—Ochromyia anthropophaga, larva.

phaga (German East Africa), and a larva of undetermined species—Lund's larva (Congo Free State).

AUCHMEROMYIA LUTEOLA (Fabricius, 1805)

Synonym.—*Musca luteola.*

History.—*Auchmeromyia luteola* was first described by Fabricius in 1805 under the name of *Musca luteola.* In January, 1904, Captain Lelean described and figured this fly, which he had collected and reared from the larva while on service with the Anglo-French Boundary Commission in Northern Nigeria. He stated that the larva occurs as a cutaneous parasite on natives near Sokoto. In July of the same year, at the Oxford meeting of the British Medical Association, Dutton, Todd and Christy gave a more detailed account of the life habits of this dipterous insect, and pointed out that in its larval stage it is a keen blood-sucker, and is known throughout the Congo as the "Congo floor maggot."

Geographical distribution. — *Auchmeromyia luteola* is widely distributed throughout tropical Africa. On the West Coast it ranges from Northern Nigeria to Natal. Dutton, Todd and Christy found it all over the Lutete and surrounding districts, and at Leopoldville. They were told that it is common at San Salvador in Portuguese territory, on the Congo at Matadi in the cataract region, and at Tchumbiri, 150 miles above Stanley Pool. An intelligent native from Lake Tchad informed them that it was common in Western Tchad regions. It was found by Neave in the Soudan.

Specific diagnosis (Fig. 205).—The fly measures from 10 to 12 mm. in length, and its body is rather stoutly built. The general colour is orange-buff, but numerous small black hairs give it a smoky appearance. The head is large, with eyes well separated in both sexes. The thorax shows two indistinct, dark, longitudinal stripes, which do not reach its posterior border. The abdomen differs in the two sexes, the second segment in the female being twice the length of the same segment in the male. The first segment has a narrow dark

stripe on its hind margin in both sexes; the second segment in the male is marked by a broader band, tapering forwards along the middle line to the base of the segment. In the female the dark band is so wide that it occupies almost the whole segment. The third segment is almost entirely black in both sexes. The fourth is dark at the base and

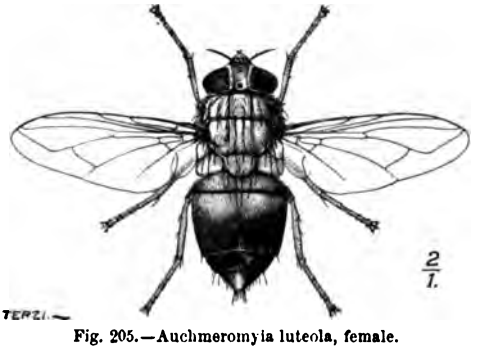


Fig. 205.—Auchmeromyia luteola, female.

lighter posteriorly. The legs are the same colour as the rest of the body. The first tarsal joint is jet black, and stands out prominently against the large cream-white pulvillus. The wings are of a smoky-brown colour with conspicuous venation.

The larva (Fig. 206) is of a dirty-white colour and semi-translucent. It consists of eleven distinct segments, and when

Fig. 206.—Auchmeromyia luteola, larva.

fully grown measures about 15 mm. in length. The central part of the ventral surface is flattened. At the posterior margin of each segment are three short limbs transversely arranged and provided with spines directed backwards. These enable the maggot to move about caterpillar-like and fairly rapidly. Laterally the segments bear two or more irregular protuberances, each of which has a posteriorly directed spine and a small pit. The anterior segment is roughly conical, and bears the mouth, which is placed between two black hooks

protruding from its apex and curved backwards towards the ventral surface of the body. Paired groups of minute teeth are placed around the two hooks so as to form a sort of cupping apparatus. The last segment is larger, depressed, and turned upwards at an angle of about 45 degrees with the rest of the body; two spiracles open on its dorsal surface, which is surrounded by spines. The anus is placed in the anterior portion of its ventral surface, and behind it are two prominent spines. The alimentary canal commences with a short œsophagus, which ends in a proventriculus. A remarkable dorsal diverticulum, corresponding to the food reservoir of the muscid larva, opens into the œsophagus near its anterior end. After the larva has fed, the diverticulum is a very conspicuous object, being seen through the semitransparent body wall as a bright-red area, extending, when full of blood, from the head to about the fifth segment. The midgut is short; the hindgut is long, much coiled, and occupies the greater part of the body cavity. The maggot has a thick integument, which enables it to withstand a good deal of pressure without injury.

The duration of the larval period has not been determined. When ready to pupate, the larva selects a suitable spot and lies dormant. The puparium is a dark reddish-brown oblong body, measuring 9–10·5 mm. in length by 4–5 mm. in breadth. The anterior end is roughly conical; the posterior is rounded. The pupa stage lasts from two to three weeks.

The fly is usually found sitting motionless amongst the thatch, beams and cobwebs of the walls and roofs of native huts, but it is very difficult to see on account of its protective colouring, which corresponds exactly with the smoke-stained straw and rafters. It never bites, is usually silent, and deposits its eggs in the dust-filled cracks and crevices of the mud-floors of the huts, particularly in spots where urine has been voided.

The larvæ are found especially under the mats on which the natives sleep, in the floor crevices, and in moist soft earth at a depth of 3 in. or more. According to Bentley, as many as fifty could sometimes be found beneath a single mattress. They feed mainly or entirely at night, and they drop off at once if the limb on which they are feeding is moved. Those who sleep on beds or raised platforms are not attacked as a rule unless the bed be low, when the maggot may reach the occupant by crawling up either the supports or the grass wall against which the bed is usually placed. The natives state that the maggot is able to jump to a height of 18 in., but this is unlikely.

LEECHES

In the grass and jungle lands of many tropical and sub-tropical countries land-leeches, probably of special species, often occur in great abundance; so much so that in some circumstances they may prove to be something more than a nuisance. The *Hæma-*

dipsa ceylonica is one of the most active, as well as best known, of these. Before feeding, when outstretched, it is about an inch in length and about the thickness of a knitting-needle. It clings to a leaf or twig awaiting the passing of some animal, on to which it springs with remarkable activity. It at once attaches itself to the skin, and proceeds to make a meal on the blood. Animals are sometimes killed in this way; men even have been known to succumb to the repeated small bleedings by these pests. It is necessary, therefore, when passing through jungle lands in which leeches abound, to have the feet and legs carefully protected. The bite is not infrequently the starting-point of a troublesome sore.

In the south of Europe and in the north of Africa the horse-leech, *Hæmopis sanguisuga*, sometimes gets into the gullet and nostrils of men as well as of animals. It has occasionally caused death by entering and occluding the air-passages. In Formosa I heard of and saw several instances of a similar form of parasitism, both in men and in monkeys. To what particular species the leech in these cases belonged I do not know. Doubtless, when very young the leeches were taken in unperceived with foul drinking-water, and, wandering round the soft palate, found their way into the nose. Occasionally, in the cases I refer to, the animals would protrude from the nares and wander over the upper lip. For a long time they contrived to elude all attempts at capture. By dipping the face in cold water they could generally be persuaded to show themselves. In one instance the leech dropped out spontaneously. In another—an American naturalist who had been travelling much in the interior of Formosa, and who had suffered from severe headache and profound anæmia, the results of repeated epistaxis—I succeeded in removing the leech by attaching through a speculum a spring forceps to its hinder end, and afterwards injecting salt and water. It would be well, therefore, to bear in mind that in tropical countries persistent headache, associated with recurring epistaxis, may be caused by a leech in the nostril.

Section VII.—LOCAL DISEASES OF UNCERTAIN NATURE

CHAPTER XLVII

CRAW-CRAW — CHAPPA — CLIMATIC BUBO — GOUNDOU—AINHUM—BIG HEEL—ONYALAI

CRAW-CRAW AND ULCERATING DERMATITIS

MOST itching papular and pustular eruptions are termed kra-kra by the natives of the West Coast of Africa. Dr. John O'Neil describes under this name a pustular affection which he says is common in certain parts of the West Coast, and which he found to be associated with the presence of a filariform parasite in the papules. O'Neil says that this form of craw-craw resembles scabies; but he adds that symptoms subside in a cooler climate, to return, however, when the negro revisits the hot and damp atmosphere of his native country. The papules occur all over the limbs and body, either singly or in rings. In two days from its appearance the papule, he says, becomes a vesicle, and in two more a pustule.

On paring off the top of the papule with a sharp knife, and teasing up the little piece of integument in water, he found a number of minute filaria-like organisms wriggling about with great activity. Their activity speedily slowed down, and in a short time the worms died. These organisms, according to O'Neil's drawings and description, resemble somewhat *mf. bancrofti*. The measurements, however, do not quite correspond, the craw-craw filaria being shorter and broader ($\frac{1}{100}$ in. by $\frac{1}{2000}$ in.) than *mf. bancrofti*; moreover, unlike the latter, it presented two black

markings at the cephalic end. He says that if the section of the papule be made sufficiently deep, five or six of these parasites may be seen in a field.

Craw-craw is said to be contagious. It appears after an incubation period of three days, and is not curable by sulphur inunction.

O'Neil's observations have not been confirmed. I think it is quite possible that the parasite he found was one of the several blood filariæ we now know to be so common on the West Coast of Africa. It is comprehensible that, in a country in which *mf. perstans* occurs in every second individual, it would be frequently found in such preparations as O'Neil examined. The removal of the top of a scabies papule would certainly be attended with some degree of hæmorrhage; in which case, should the patient chance to be the subject of any form of filarial infection, microfilariæ would be found in the preparation. Immersion in water would, as in the case of O'Neil's parasite, quickly kill the parasites. I do not wish to assert that O'Neil's parasite was *mf. perstans*, but the possibility of this must not be overlooked.

A disease resembling O'Neil's craw-craw was described some time ago by Prof. Nielly under the title *dermatose parasitaire*. A French lad, who had never been abroad, became affected with a papulo-vesicular itching eruption resembling scabies, in which Nielly found a filariform parasite somewhat like that discovered by O'Neil in craw-craw. It had the same peculiar cephalic markings; in addition, it had a well-defined alimentary canal and rudimentary organs of generation. Nielly found nematode embryos in the blood in this case; so that we are justified in believing that the parasite in the skin was an advanced developmental form of the embryo in the blood, and that both were the progeny of a mature parental worm living somewhere in the tissues. Possibly Nielly's *dermatose parasitaire* and O'Neil's craw-craw were of the same nature.

Symptoms.—The term craw-craw is very loosely applied. Emily has described under this name a

papulo-pustular skin affection which is common in certain parts of tropical Africa, and which is often the cause of much suffering to the traveller. It, or a similar disease, is by no means confined to Africa, for I have seen it in patients from India, and was at one time very familiar with it in South China. At the earliest stage the disease begins as an itching papule, very possibly at the seat of a mosquito bite. The itching provokes scratching, whereby some form of pyogenic micro-organism is inoculated. Pustulation follows, and is spread over feet and legs by soiled shoes and stockings and auto-inoculation. In this way an ulcerating, pustulating dermatitis is kept up. The veld sore of South Africa, if not the same, is a similar disease.

Treatment.—Emily describes a very efficient treatment. Pustules are opened, crusts removed, and ulcers scraped. Boric-acid powder is then dusted freely on the parts after a thorough scrubbing with sublimate lotion (1–1,000), boricated vaseline applied on lint, and over all absorbent cotton and a bandage. The dressings are not disturbed for a week, when the parts will be found soundly healed. Such and similar auto-infective diseases of the hands and feet, so common in the tropics, I used to treat with a foot-bath of warm carbolic-acid lotion (1–20), followed by dry dressing with abundance of boric-acid powder, at the same time insisting on destruction of infected slippers, shoes, and stockings.

CHAPPA

Under the name "chappa" Read describes a disease which he has met with in the western district of the colony of Lagos. During two and a half years he has seen six examples, two in males, four in females. He thus describes it :—

"The patients all give the same history. The disease commences with severe pains in the limbs, muscles, and joints. After a few months the pain decreases, and some joints begin to swell and convey the sense of fluctuation. About the same time nodules develop in different parts of the body. These nodules are in the subcutaneous tissue, and are about

the size of a pigeon's egg. After a time, without the formation of an abscess, the skin over the nodule ulcerates and exposes a circular or oval ulcer with a fatty-looking base. The nodules may be single, but are more often multiple, and may be so close together that when ulceration ensues the ulcers coalesce, forming a serpiginous ulcer. Sometimes the nodules are absorbed without proceeding to ulceration. The ulcers are very chronic and last for years, sometimes healing at one place and gradually extending in another. The joints I have seen most affected are the knee, elbow, and wrist. The sense of fluctuation was so marked in one case that I opened the joint; but no fluid exuded, a fatty-looking material protruding through the incision. The disease after a time attacks the bones, and the joints may become totally disorganized." —(*Journ. of Trop. Med.*, Oct. 15, 1901.)

On comparing the photographs illustrating Read's paper with others of a very similar complaint common among the natives in certain parts of British East Africa, I am inclined to think both sets of photographs represent identical conditions. Possibly "chappa" is a tertiary phase of yaws.

Treatment.—Neither potassium iodide nor mercury avails. Scraping, escharotics, and antiseptics seem to be more effective; but, although the disease may heal under treatment in one place, it breaks out in another.

Climatic Bubo

Scheube has applied the term "climatic bubo" to a type of non-venereal adenitis not uncommon in tropical climates. So far as available statistics show, the disease is especially prevalent among the crews of warships on the eastern coast of Africa. It occurs also in the Straits of Malacca, in China (where I have seen a fair number of cases both in landsmen and in sailors), in the West Indies, Japan, the Mediterranean, and probably in many other places, including, perhaps, in a minor degree, Europe. It appears to be epidemic at times in certain places, and to prevail in groups of individuals living under similar hygienic conditions. Thus, Ruge reports 38 cases in the German squadron blockading the Zanzibar coast in 1888–89; Godding notes its frequency in the British fleet, also on the East African coast;

Skinner mentions 49 cases occurring in a regiment and battery of artillery: of these, 28 developed in Calcutta, 13 in Hong Kong, 4 in England, 2 in Allahabad, and 2 in Malta.

Symptoms.—The disease generally commences with fever of a remittent type in association with inflammatory swelling, usually of a subacute character, of the groin glands. The oblique inguinal glands are those most frequently affected, but at times it is the crural glands that are attacked. Sometimes both groins are affected, sometimes only one, sometimes one groin is attacked after the other. The affected glands slowly or more rapidly enlarge to the size of a hen's egg, or even larger. After several weeks, it may be months, the swelling gradually subsides. Occasionally the periglandular connective tissues inflame, the integuments become adherent, and suppuration ensues. If the suppurating glands be freely incised, or excised, the parts readily heal; but if they are left alone, or inefficiently treated, fistulous tracks form and may take a very long time to heal.

Hitherto no satisfactory explanation of this type of adenitis has been forthcoming. No special bacterium has been demonstrated in the tissues. There are no adequate reasons for supposing, as has been conjectured, that the disease has any connection with plague, or that it is a form of pestis minor. Most probably the adenitis depends on some virus which has been introduced through an overlooked wound or insect bite on the legs or genitals.

Treatment should consist in rest and soothing applications during the more acute stage. After pain and tenderness have subsided, graduated elastic pressure should be applied. Concurrent malaria would call for quinine; syphilis, for mercury or the iodides.

Goundou, or Anakhre ("Gros Nez")

On December 10th, 1882, Prof. A. MacAlister read a paper before the Royal Irish Academy on what were termed the horned men of Africa. In the *British Medical Journal* of December 10th, 1887,

Lamprey gave further details, illustrated with drawings, on the same subject. He had seen three such cases on the West Coast of Africa, all of them Fantis; one came from the Wassau territory, one from the Gamin territory, the third was a visitor to Cape Coast Castle. Renner also reports and illustrates a case from the Sierra Leone River.

Maclaud calls attention to what is manifestly the same affection, which, according to him, occurs in a considerable proportion—one or two per hundred—of the inhabitants of certain villages on the Ivory Coast. The natives call it *goundou*, and, also, *anakhre*. Maclaud says it is confined to the riverine districts of the lower Camoe; according to the information he received, if found elsewhere it is only in individuals who had previously resided in this district. Lamprey's and Renner's observations prove that goundou has a considerably wider distribution.

Symptoms.—According to Maclaud, the disease usually commences soon after childhood, although adults also may be attacked. The earliest symptoms are severe and more or less persistent headache which, after a time, is associated with a sanguino-purulent discharge from the nostrils, and the formation of symmetrical swellings the size of a small bean at the side of the nose. (Fig. 207.) Apparently the swelling affects the nasal process of the superior maxilla. The cartilages are not involved. Although Maclaud does not refer to this point, it may be assumed that the nasal ducts remain patent. After continuing for six or eight months, the headache and discharge subside. Not so the swellings; these persist and continue slowly and steadily to increase until in time they may attain the size of an orange, or even of an ostrich's egg. As they grow, the tumours, encroaching on the eyes, may interfere with the line of vision and finally destroy these organs. There is no pain in the tumours themselves. The superjacent skin is not involved, being healthy-looking and freely movable. The tumours are oval, with the long axes directed downwards and slightly from within outwards. Lamprey's drawings

give a more elongated form and horizontal direction. The swellings, according to Maclaud, when of moderate dimensions, look something like two half-eggs laid alongside the nose, one on each side. The nostrils are bulged inwards, and more or less obstructed; but, in the later stages at all events, there is no discharge, neither can any breach of the mucous surface be detected. The hard palate is not affected in any way.

Maclaud had no opportunity of ascertaining by post-mortem examination, or by surgical operation,

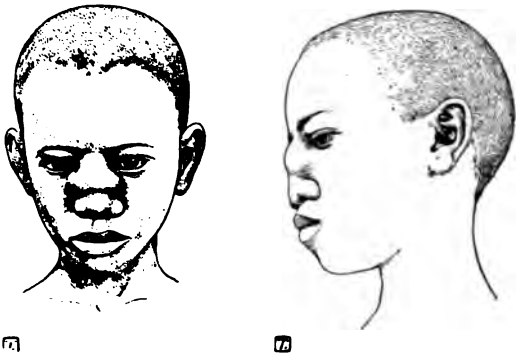


Fig. 207.—Goundou. (*From photograph in the Journ. of Trop. Med.*)

the nature of this singular disease. He inclines to the opinion that, in the first instance, the process is started by the larvæ of some insect which find their way into the nostrils. I would point out, however, that the symmetry of the growths is difficult to account for on this hypothesis. Maclaud observed a similar affection in a chimpanzee.

Strachan records and illustrates an instance of goundou in a West Indian negro child. (Fig. 208.) In this case the swellings were congenital, and had only increased in proportion to the child's growth. They were hard, smooth, bony masses, somewhat of the shape and size of an elongated pigeon's egg, and sprang from the nasal process of the superior

maxillary and nasal bones. For æsthetic reasons they were removed by the chisel, and were found to consist of compact bone with a cancellous core. Strachan states that he had seen two similar cases, and had often noted a "ridge" in this part of the face of West Indian negroes. He suggests that the condition may be an example of atavism, referable to some tribal peculiarity of the original West African stock.

Chalmers has given an admirable and well-

Fig. 208.—Goundou in a West Indian child. (*Dr. Henry Strachan.*)

illustrated account of this affection as seen on the Gold Coast, where it is fairly common and is known as "henpurge." He confirms Strachan as to the anatomical characters of the swellings, which he regards as the result of an osteoplastic periostitis due to yaws. He affirms that the morbid process begins during, or soon after, an attack of yaws, and is correlated in some way to an anatomical arrangement of the blood-vessels of the parts, an arrangement which, he gives the reader to infer, is peculiar to the negro of this part of Africa.

AINHUM

This is a disease of a very peculiar character, affecting the toes, particularly the little toes, of negroes, East Indians, and other dark-skinned races.

Symptoms.—The disease commences as a narrow groove in the skin almost invariably on the inner and plantar side of the root of the little toe. It may occur in one foot only, or in both feet simultaneously, or it may affect one foot after the other. The groove, once started, deepens and extends gradually round the whole circumference of the toe. As it deepens—it may be, though not necessarily, with some amount of ulceration — the distal portion of the member is apt to swell to a considerable size, as if constricted by a ligature. (Fig. 209.) There is little or no pain, although there may be inconvenience from the liability to injury to which the dangling and now everted toe is exposed. In the course of years the groove slowly deepens, and finally the toe drops off or is amputated. The groove may either correspond with a joint or it may be formed over the continuity of a phalanx. In rare instances, after the two distal phalanges have dropped off or been amputated, the disease recurs in the stump, and the proximal phalanx in its turn is thrown off. Of the other toes, the fourth is the one which is most frequently affected; very rarely is the third, or second, or great toe attacked. In the Army Medical Museum at Washington, U.S.A., there is a wax model representing a case of this or a similar affection, in which all the toes had been thrown off and the disease was making progress in the leg.

Fig. 209.—Ainhum.

Ainhum is very rare in women or children, being

most common in adult males. It runs its course in from one to ten or even more years.

On section it is found, as a rule, though not invariably, that the panniculus adiposus of the affected toe is much hypertrophied, that the bone is infiltrated with fatty matter, and that the other tissues are correspondingly degenerated. Sometimes the bone is thinned, or even altogether absorbed. At the seat of constriction a line of hypertrophy of the epithelial layers, and of atrophy of the papillary layer of the skin, together with a band of fibrous tissue more or less intimately connected with the derma, surrounds, in whole or in part, the narrow pedicle.

Nothing is known as to the true nature and cause of this disease, to which the European and white-skinned races are not, but to which the African races, particularly the negroes of the West Coast, are specially liable. Some have suggested that it is a trophic lesion depending upon some nervous affection. The occurrence of severe loin pains, which Dupouy says he remarked at the commencement in some of his cases, as well as the tendency of the affection to run in families, as noted by Da Silva Lima, afford a certain amount of support to this view. Others suggest that it is a manifestation of leprosy; others, that it is a form of sclerodermia; others again, and on equally inadequate grounds, that it is produced artificially by intentional ligation or by the wearing of toe rings. My own impression is that it is provoked, at all events in the first instance, by wounds—so easily inflicted on bare feet in walking through grass or jungle. The fold of skin in which the lesion of ainhum commences is very liable, especially in the splayed-out toes of the negro, to be wounded in this way. If we examine the under surface of the joint flexures of the toes in many individuals of this race, even of those not affected with ainhum, we often find the skin, particularly at the proximal joint of the little toe, thick, rough, scaling, and sometimes even ulcerated. One can understand that continual irritation of this sort, produced and kept up by wounds from sharp grasses or jiggers (Wellman), would in time give

rise, especially in the dark-skinned races so prone to cheloid, to fibrotic changes in the derma, which might very well end in a sort of linear cicatricial contraction, and ultimately in slow atrophying strangulation of the affected member. The disease is said, however, to have been seen in those who wear shoes; but, unless it could be shown that such individuals had always worn shoes, this objection to the explanation offered would not apply. I have seen a negro in whom the entire integument of the little toe was involved in a sclerodermia, and the part in consequence was shrunken and hidebound, whilst the little toe of the other foot was affected with well-marked ordinary ainhum; the process was diffuse, as it were, on the one side, localized on the other.

The tail in certain species of monkey is liable to a similar disease. I have had under observation for some time a pet monkey in which the part corresponding to the distal vertebra dropped off in consequence of an ainhum-like linear constriction. Two months later the next vertebra was similarly amputated, and later a third groove formed a little higher up the tail.

Treatment.—It has been suggested that division of the constricting fibrous band would delay the evolution of the disease. In the early stage this might be tried. When troublesome, the affected toe should be amputated.

Big Heel, or Endemic Hypertrophy of Os Calcis

MacLean (*Journ. of Trop. Med.*, Nov. 1, 1904) describes a peculiar form of enlargement of the os calcis which he observed at Kaziankor, Gold Coast, West Africa, among Fantis and Kroos. The disease begins somewhat suddenly, being preceded by fever and accompanied by pain and tenderness which reach their maximum in about a month, gradually diminishing during the succeeding one or two months. Concurrently with the pain a swelling of the external surface of the os calcis, rarely of the tarsal bones, makes its appearance. Sometimes one heel only,

sometimes both heels are affected. The swelling may be so considerable as to be quite evident both to touch and sight. It subsides to a certain extent, though not altogether, as the pain diminishes. Locomotion is seriously interfered with by the pain, but there is no implication of joints. The disease relapses from time to time, more especially during the rainy season. In one case recorded by MacLean severe pain would be provoked at any time by application of cold water.

Maxwell (*Journ. of Trop. Med.*, March 15, 1905) reports a similar condition in natives of Formosa. As in MacLean's cases, the patients were young adults from 20 to 25 years of age. In Maxwell's cases the disease, although very painful, seemed to be of a more chronic character. In one instance the patient's sufferings were much relieved by trephining the affected bones. This curious condition somewhat resembles goundou. So far, we have no clue to its etiology. It is probably not syphilitic. Iodide of potassium did not relieve Maxwell's cases.

ONYALAI

Yale Massey describes (*Journ. of Trop. Med.*, Sept. 1, 1904, April 1, 1907), under the above title, a peculiar disease occurring among the natives of Portuguese West Africa, and also on the Lualaba River. It is characterized by the formation of a number of vesicles, distended with blood, from ¼ to ½ in. in diameter, on the hard palate and on the inside of the cheeks. Some of the vesicles are umbilicated. They differ from ordinary blood blisters by the presence of numerous trabeculæ and the semi-coagulation of the contents; this makes the vesicle difficult to empty. The urine apparently invariably contains free blood. Occasionally the disease is accompanied by fever, and although with one exception all Yale Massey's cases recovered within a week to ten days, the natives regard the disease with dread owing to its reputation for deadliness. The etiology is quite unknown.

Appendix

SOME OF THE COMMONER PARASITIC PROTOZOA OF VERTEBRATES AND INVERTEBRATES

RECENT discovery has clearly demonstrated the importance of the Protozoa as factors in the etiology of disease, especially of tropical disease.

Manifestly the subject is still in its infancy. Many as yet unknown species of blood protozoa will doubt less be added to the already considerable list of those attacking man and the lower animals. As regards man, it is doubtful if we have as yet completed the list even of the much-studied malaria parasites, much less determined their respective life histories and zoological relationships. Moreover, there are certain genera of blood protozoa which, although occurring in other mammals, have, so far, not been found, or, at all events, recognized in man, Babesia and Hæmogregarina for example. It is not unreasonable to conjecture that, although hitherto unrecognized, representatives of these genera do occur in man, and that ere long they will be discovered. The investigator must not lose sight of this probability.

The entire subject is one of the utmost importance to the medical man in the tropics, and, whether he would perfect himself in existing knowledge or seek to add to it, he should study it practically and from the standpoint of comparative pathology. I would therefore strongly recommend him to avail himself of the abundant opportunities he is sure to enjoy to study the protozoa not in man only but in other mammals, in birds, in fishes, and in reptiles. As a guide and help in such studies I append a brief summary, for which I am indebted to Dr. Philip Bahr, of our present knowledge of this important class of

parasites, so far as it has a bearing on human pathology. As to classification, still a *quæstio vexata*, the one adopted in Prof. Minchin's "Introduction to the Protozoa" (1912) has been for the most part followed.

DEFINITION OF THE PROTOZOA

Protozoa are unicellular organisms possessing a nucleus distinct from the cytoplasm. They belong to the Protistenreich of Haeckel, a kingdom which unites the simplest and most primitive forms of life, and which may be considered equivalent in systemic value to the animal and vegetable kingdoms.

The protozoal cell constitutes an entire individual; it may exist singly, or combined in the form of cell colonies.

The body is a mass of protoplasm sometimes enclosed in a limiting envelope. Such organs as are present are also protoplasmic, and are used for the purposes of locomotion and capture of food. Metabolism is generally of the animal type.

Reproduction takes place by fission. Sexual reproduction generally occurs throughout the group, and, as compared with other Protista, the developmental cycle may be a very complicated one in which the same organism reappears in a totally different form at different periods of its development.

There are certain forms of development in the blood protozoa which it is necessary to define and for which certain terms are used. Their application, however, when loosely used has given rise to much confusion. The protozoa parasitic in blood of the vertebrate host undergo a vegetative or non-sexual multiplication, the process being then known as *schizogony*; but in order to ensure their further existence, and their passage from one vertebrate host (intermediary host)* to another, a further cycle in a cold-blooded invertebrate host (definitive host) is necessary, during which the sexual cycle or *sporogony* takes place.

In the vertebrate blood the young parasite is known as a *schizont*. The products of the asexual fission are known as *merozoites*; these merozoites at some period of their existence develop into forms known as *sporonts*, destined to pass into the alimentary tract of the invertebrate host. The term *trophozoite*

* The terms "intermediary" and "definitive," as describing the vertebrate and invertebrate host, have often been used in a loose sense, thus leading to much confusion.

is applied to the young schizont or sporont which is absorbing nourishment direct from the cell in which it is lodged.

Parthenogenesis is not recognized as occurring in the protozoa, but was supposed by Schaudinn to take place in the case of the malaria parasite and to be responsible for the relapses of that infection.

These sporonts, still in the blood of the vertebrate host, develop into sexually differentiated cells (*gametocytes*), which are quiescent until they are removed from the blood; when this occurs both male and female cells extrude two polar bodies preparatory to the sexual process, and are then known as *gametes*. The flagella or *microgametes* extruded by the male cell function as spermatozoa, and enter and fertilize the female cell (*macrogamete*), thereafter known as a *zygote*.

After this act the zygote in some forms, especially the Plasmodidæ, becomes an elongated motile body (*oökinete* or travelling vermicule), which may remain free or become encysted (*oöcyst*). The oöcyst gives rise to secondary bodies in its interior (*sporoblasts*), which in turn develop into a number of minute rods known as *sporozoites*. Usually these sporozoites continue to enter the mouth parts of the insect, and by this route they once more gain the blood of the vertebrate host.

The Protozoa are generally divided into four main classes.

Class I.—SARCODINA

Protozoa in which the protoplasmic body has no limiting envelope in the form of a stiff cortical layer, thus tending to a spherical shape in the floating forms, or an irregular, ever-changing shape in the creeping forms. Organs serving for locomotion and capture of food are known as *pseudopodia*; a skeleton or shell may be present. Encysted resistant forms occur which may give rise to a number of daughter cells.

Sexual conjugation (*gametogamy*) is the usual process of reproduction, though *autogamy* within the cyst wall has been described.

EXAMPLES: *Amœba limax, Entamœba coli, Entamœba histolytica.*

Class II.—MASTIGOPHORA

Protozoa in which the organs of locomotion and for food capture are *flagella*, that is to say, long slender filaments capable of performing lashing movements.

EXAMPLES: *Trichomonas, Lamblia, Trypanosoma.*

Class III.—SPOROZOA

Protozoa occurring as blood or intracellular parasites of other organisms. They possess no definite organs for locomotion or for ingestion of food. The typical reproduction takes place by the formation of spores and minute germs called *sporozoites*.

EXAMPLES: *Gregarina, Coccidium, Plasmodium.*

Class IV.—INFUSORIA

Protozoa in which small filaments called *cilia* serve as organs of locomotion; these are distinguished from flagella by their much smaller size and in being present in great numbers, forming a fine covering over the whole of the body. The body protoplasm is always corticate.

EXAMPLE: *Balantidium.*

Class I.—SARCODINA

This class, sometimes termed the Rhizopoda, includes parasitic amœbæ as well as free-living forms such as the Radiolaria and Foraminifera; these latter are of little interest to the student of tropical medicine. The distinctive characters of the amœbæ parasitic in man have already been given (p. 504). These are capable of independent amœboid locomotion by the alternate protrusion and retraction of protoplasmic processes called "pseudopodia."

Entamœba coli reproduces itself by binary fission in the ordinary way; this is called the vegetative or multiplicative phase. In addition to this a cystic or resting stage occurs, when conditions under which the parasite exists become adverse.

A sexual process, called *autogamy*, occurring within the cyst wall was described by Schaudinn, though recent authorities are inclined to doubt it. The process, as described, is as follows: The cyst contains at first but one nucleus, which divides into two. Each nucleus is then said to break up into chromidia and disappear, but to reappear later as a smaller and less distinct secondary nucleus on each side of the cell. Each secondary nucleus again divides into three; two of these again degenerate as reduction nuclei, while the third persists as a sexual or gameto-nucleus. The gameto-nuclei divide into four pronuclei, then two of each side conjugate and fuse, forming two nuclei or "*synkarya*" which subsequently divide into eight nuclei, in this manner forming eight amœbulæ within the cyst.

The end-product of the cystic stage of *Entamœba histolytica* possesses but four nuclei, and is known as the *Entamœba tetragena*

of Viereck. The process of cyst formation by a budding process of the vegetative form, as described by Schaudinn, is now held to be incorrect.

The vegetative forms of the pathogenic and non-pathogenic species are further distinguished by differences in their protoplasmic contents. In *E. histolytica* the endoplasmic zone is granular, the ectoplasmic hyaline, while in *E. coli* no such differentiation occurs. The nuclei of the two forms have also distinctive differences. *E. coli* has a large and distinct nucleolus (*karyosome*) and a distinct nuclear membrane; whereas the *E. histolytica* nucleus is not so markedly differentiated (*see* p. 503).

Amœba limax and *A. terricola* are free-living forms of amœbæ occurring in water and earth. Their cystic stages possess a hard and refractile cyst wall. They are of importance to the tropical pathologist in that they may be ingested and recovered from the stools of dysenterics and others in culture on Musgrave and Clegg's medium. The parasitic amœbæ proper to man have not been so cultivated.

Class II.—MASTIGOPHORA

The Mastigophora are divided into three subclasses, of which only one subclass, that of the *Flagellata*, containing the more typical forms, deserves our attention. The subclass Flagellata is divided into four orders:

i. Pantasomina.
ii. Protomonadina.
iii. Polymastigina.
iv. Euglenoidina.

The second and third only of these orders contain parasitic genera.

Order ii.—Protomonadina

The Protomonadina are mostly flagellates of a small size with a principal and one or more subsidiary flagella. They are either saprophytic or parasitic.

Suborder 1.—Cercomonas is a frequent parasite in the intestine of man; it is oval in shape, with a single nucleus and well-marked nucleolus, and has two flagella, one passing forwards, and the other backwards over the surface of the body to the hinder end, which is frequently drawn out into a protrusion resembling a tail.

Suborder 2.—Bodo (Fig. 210) is similar in shape and general structure to Cercomonas, but has two flagella, one directed forwards, the other backwards as a trailing flagellum; it occurs both as free-living forms and as parasitic in animals, for the most part in the digestive tract.

Suborder 3.—Prowazekia.—Prowazekia resembles Bodo in the arrangement of its flagella, but in the possession of a tropho- and a kinetonucleus it more resembles Trypanoplasma. It differs from Trypanoplasma in that the backward-directed

flagellum is free from the body and devoid of an undulating membrane. Several species have been described from human fæces, and one, *P. cruzi*, is considered to be the cause of a diarrhœa in China.

Suborder 4.—The **Hæmoflagellata** and allied forms are an important suborder of the Protomonadina, and under this term are grouped a number of forms having a characteristic but not invariable parasitic habitat in the blood of vertebrates and in the digestive tract of invertebrates.

The group comprises a number of heterogeneous forms conveniently grouped together, their chief morphological feature being the possession of two nuclei, a tropho- and a kinetonucleus (blepharoplast). For this reason they were included by Hartmann as a distinct order of the Flagellata and termed the "binucleata."

The following five genera represent the more important types: (1) Trypanosoma, (2) Trypanoplasma, (3) Crithidia, (4) Herpetomonas, (5) Leishmania.

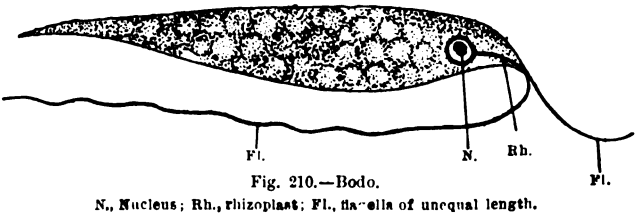


Fig. 210.—Bodo.

N., Nucleus; Rh., rhizoplast; Fl., flagella of unequal length.

1. The genus Trypanosoma.—The structure of the trypanosome body is of a uniform type, though subject to variation in minor details. The body is long and sinuous; the anterior * end tapers gradually to a narrow point, while the posterior end generally terminates more bluntly.

The principal nucleus (trophonucleus) is situated centrally; the kinetonucleus is usually placed posterior to the nucleus, but is sometimes closely approximated to it. Certain exceptions to this rule are known, namely, the recently described *T. rhodesiense* (p. 183), and some multiplicative forms of *T. lewisi*. The flagellum arises from a centriole (blepharoplast) closely connected with the kinetonucleus, and passes forwards as the margin of the undulating membrane; in some cases it may end with the undulating membrane at the anterior extremity of the body, but more usually it projects forwards as a free lash. The arrangement of the centriole and kinetonucleus varies; sometimes the former is lodged within the latter, sometimes connected with it by a delicate rhizoplast. In one species,

* It has been suggested that the terms "flagellar" and "aflagellar" be used to designate the extremities of the body, instead of the terms "anterior" and "posterior," which are here employed strictly with reference to the mode of progression.

T. equinum (Fig. 211), the cause of "mal de caderas" in South America, the kinetonucleus is very minute.

Trypanosomes occur as blood parasites in all classes of vertebrates. Many wild animals harbour small numbers of these parasites in their blood. Certain are specific and probably harmless to their particular vertebrate host.

Fig. 211. T. equinum. (*After Laveran.*)

Trypanosomes of cold-blooded animals include *T. rajæ*, *T. damoniæ*, *T. granulosum*, and *T. rotatorium* (Figs. 212–5).

Though showing but slight morphological differences as a general rule, members of this genus have been differentiated on morphological as well as on pathological grounds.

The *Lewisi* group includes *T. lewisi*, *T. cuniculi*, *T. duttoni* of the mouse, *T. microti* of *Microtus arvalis*, all about equal in size (24–25 μ in length and 1–2 μ in breadth), and similar in

Fig. 212.—T. rajæ. (*After Laveran and Mesnil.*) A trypanosome of fish (the skate).

Fig. 213.—T. damoniæ. (*After Laveran and Mesnil.*) A trypanosome of the tortoise (Damonia revesi).

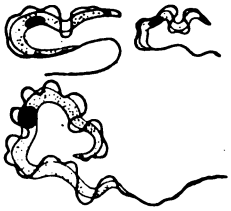


Fig. 214.—T. granulosum. A trypanosome of the eel.

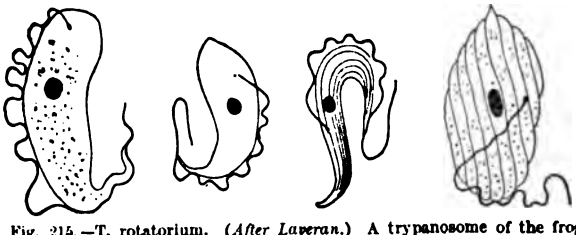


Fig. 215.—T. rotatorium. (*After Laveran.*) A trypanosome of the frog (Rana esculenta).

general appearances; that is, the organisms are long and slender; both the flagellar and aflagellar extremities are markedly pointed and the nucleus situated towards the flagellar end. They are non-pathogenic, or only slightly pathogenic.

The *Brucei* group includes nearly all the pathogenic varieties: *T. brucei* (nagana), *T. gambiense* (sleeping sickness), *T. rhodesiense* * (human trypanosomiasis in Rhodesia), *T. evansi*

* *T. rhodesiense* greatly resembles *T. gambiense*, but is more pleomorphic and more virulent to the lower animals.

(surra), *T. hippicum* (murrina, a disease of mules in Panama), *T. equinum* (mal de caderas), *T. equiperdum* (dourine, or mal du coït), *T. vivax* vel *cazalboui* (souma disease of mules and cattle in the Soudan).

These trypanosomes are all about the same size (22–28 μ in length and 1–3 μ in breadth). The aflagellar extremity is blunted to a variable extent, the nucleus is centrally placed, and the protoplasm granular. For further details of the members of this group, *see* p. 190.

According to some authors, *T. dimorphon*, a parasite of horses in the Gambia, producing symptoms resembling nagana, represents a distinct type. As its specific name implies, it is found in two distinct forms—one long form, 22 μ in length; and a short, stumpy form, 1–5 μ in length. The aflagellar extremity is markedly blunted, and the body protoplasm is continued to the end of the flagellum.

T. nanum resembles *T. dimorphon* in general features, and is the smallest of all the mammalian trypanosomes, measuring 11–16 μ by 2·5 μ. It produces a chronic disease, marked by emaciation and anæmia, in cattle in the Soudan.

T. theileri (Fig. 216), 60–70 μ in length by 4 μ in breadth,

Fig. 216.
T. theileri.
(*After Laveran.*)

Fig. 217.
T. lewisi.
(*After Laveran.*)

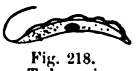


Fig. 218.
T. brucei.
(*After Laveran.*)

one of the largest mammalian trypanosomes, is recognized by its large size and rapid movements. It is apparently non-pathogenic, and is transmitted, according to Theiler, by *Hippobosca rufipes*. *T. ingens*, found in cattle in Uganda, is still larger than *T. theileri*, measuring 72–122 μ in length, and the flagellum alone measuring 17 μ.

The transmission of these trypanosomes from one host to another is carried out, so far as is known, by the agency of some blood-sucking invertebrate. When such a host is of terrestrial habit the definitive host is an insect, when aquatic a leech; though in one species, *T. equiperdum*, the cause of "dourine" in horses, the trypanosomes may pass from one host to another during coitus. Hereditary transmission in trypanosomes has not yet been proved. One or more species of insect may serve as the definitive host; thus in *T. lewisi* the selective hosts are the rat-fleas (*Ceratophyllus fasciatus* and *Xenopsylla cheopis*), though it may also develop in a different genus, the rat-louse (*Hæmatopinus spinulosus*) and also in *Pulex irritans* and *Ctenocephalus canis*.

The life cycle in the vertebrate host is generally as follows: After infection (as in *T. lewisi*, Fig. 217) the trypanosomes appear in the blood about the fifth to the seventh day. Owing to the rapidity with which fission takes place the

forms are of great variety. After two or three months have elapsed the swarms of trypanosomes in the rat's blood have begun to diminish and eventually disappear. When this has taken place that rat is immune to that particular species of trypanosome.

No confirmation of Schaudinn's statement that some part of the development of trypanosomes in the blood is ultra-microscopic has been made, though filtrations of infected blood plasma through a bacterial filter have been experimented with. Fry and Ranken have observed a process of granule-shedding in trypanosomes under the dark-ground illumination (*see* p. 159).

In some instances trypanosomes appear in the peripheral circulation only at certain periods, as in the case of *T. rhodesiense* in man; and in others, as in the trypanosome of *Athene noctua*, the little owl, they are said to be most numerous in the peripheral circulation during the night-time, and then only during the summer months; in the winter months they are found in the bone marrow.

The cycle in the invertebrate host takes place mainly in the digestive tract. Thus, *T. lewisi*, after being imbibed by the flea, multiplies rapidly, chiefly in the stomach cells, subsequently passing into the hindgut and rectum. Here the parasites assume a leptomonas and crithidia appearance, and occur in large bunches attached by their flagellar ends to the epithelium, where they divide with great rapidity, or they may occur in cyst-like masses within degenerating epithelial cells. Eventually they give rise to the small infective trypanosomes first described by Swellengrebel and Strickland, which occur in vast numbers in the hind-gut and rectum of the flea. The latter becomes infective in four to seven days, and it may remain infective for forty-five days or longer. The flea does not infect the rat through its proboscis, and the parasites are not found in the flea's salivary glands. Theoretically infection can take place in three ways: (*a*) the flea harbouring the infective forms of the flagellates may be crushed and devoured by the rat; (*b*) the rat may lick its fur upon which an infected flea has just dejected; (*c*) the rat may lick and infect with flea dejecta the wound produced by the insect. Of these the second is probably the most common method; the other two are doubtful.

Many pathogenic trypanosomes in Africa are transmitted by tse-tse flies (*Glossina*), and probably these flies remain infective for life. Thus, *T. gambiense* of man is transmitted by *Glossina palpalis*, and perhaps by *G. morsitans* as well; *T. brucei* (*T. pecaudi*) (Fig. 218) of big game, and *T. rhodesiense* of man, by *G. morsitans*; *T. vivax* (probably identical with *T. cazalboui*) by *G. morsitans*, *palpalis*, *longipalpis*, and *tachinoides*; *T. capræ* by *G. morsitans*; *T. dimorphon* by *G. palpalis*; *T. grayi*, the trypanosome of crocodiles, is also transmitted by this same glossina; *T. evansi*, of "surra," a disease of horses in India, by *Stomoxys nigra*, and probably by a tabanus as well.

The trypanosomes of birds probably develop in mosquitoes; those of fishes and turtles in leeches.

Two methods of transmission of trypanosomes must be distinguished. The one, a mechanical method, can be performed by any blood-sucking insect for a few hours after a meal of infected blood; the other, indirect or cyclical, is a developmental cycle, and can only take place in the particular definitive host—that is, in most instances, some species of glossina—to which the particular species of trypanosome has become adapted.

The development of *T. gambiense* (Fig. 219) in *G. palpalis*, thanks to the researches of Kleine, Taute, Bruce and his collaborators, is now fairly completely known. Apparently the whole development takes eighteen to twenty-five days or more. Five to seven days after ingestion of infected blood the trypanosomes become scarce in the digestive tract of the fly, only to reappear in large numbers and in a variety of crithidial and other forms. Finally an invasion of the salivary glands by short, stumpy, trypaniform individuals takes place. In *T. vivax* (*cazalboui*) a completely different mode of development in glossina takes place, a method termed by Roubaud *évolution par fixation directe*; this occurs solely in the proboscis of *Glossina palpalis*. The trypanosomes assume a leptomonas shape and attach themselves by their flagellum to the labium or hypopharynx of the proboscis tube, multiplying in the salivary fluid; these flies remain infective for life. A third method of development occurs in the case of *T. dimorphon*—the *évolution par fixation indirecte* of Roubaud. In this case the trypanosomes multiply first in the digestive tract of the glossina, and then pass forwards into the proboscis.

Fig. 219.
T. gambiense.

In *T. cruzi* the development both in the intermediary and in the definitive host is of so different a character that Chagas has relegated it to a special genus, *Schizotrypanum*. In man the adult trypanosomes multiply not in the peripheral circulation but in the internal organs of the body. In the capillaries of the lungs the adult trypanosome loses its flagellum and occasionally the kinetonucleus as well, the body becomes round, and the mass breaks up into eight small individuals (merozoites). Some regard these merozoites as exhibiting a sexual differentiation. The merozoites enter the red blood-cells, and so gain the general circulation. Within the corpuscles they form into a normal trypanosome, which, when set free, either repeats the schizogonic cycle or enters into the invertebrate host, in which it develops still further.

A second type, and probably the normal method of multiplication in man, takes place within the hypertrophied endothelial cells of the lung and striped muscles, notably the cardiac muscle, but can apparently occur in any tissue.

In this situation the parasite assumes the shape and appearance of a leishmania.

The developmental cycle of this trypanosome takes place in a bug, *Lamus megistus*, and is shortly as follows: The trypanosomes taken up into the bug's stomach change in about six hours; having lost their flagellum they assume a leishmania form and multiply by fission. After a while these forms assume a crithidial shape and pass into the intestine, eventually gaining the body cavity and salivary glands of the insect as small trypanosomes, and in this manner pass into the vertebrate host.

The changes undergone by trypanosomes in culture on N.N.N. medium (p. 156) are diverse and striking; they then exhibit a series of forms quite distinct from those seen in the blood of the vertebrate, but bearing more resemblance to those seen in the invertebrate host. In such cultures they assume crithidial, leptomonas, and even leishmania forms.

Fig. 220. Trypanoplasma borreli. (*After Laveran and Mesnil.*)

2. The genus Trypanoplasma (Fig. 220).—The species of this genus parasitic in blood are only known as yet to occur in fresh-water fishes, and are transmitted by leeches. A number of species are parasitic in the organs of snails, such as *T. helicis*, found in the receptaculum seminis of *Helix pomatia*. The principal feature is the presence of two flagella arising together from two blepharoplasts at the anterior extremity. One flagellum projects forwards, passing down the side of the body to the hind end, forming the free

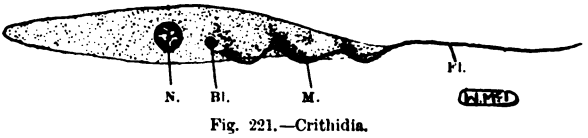


Fig. 221.—Crithidia.

Fl., Flagella; M., undulating membrane; Bl., blepharoplast; N., nucleus.

edge of the undulating membrane and projecting freely backwards as a free flagellum.

3. The genus Crithidia (Fig. 221).—The distinctive feature of this genus is the relatively short undulating membrane and flagellum arising from the centre of the body at a point in close proximity to the kinetonucleus. The shape of the body varies considerably. Crithidial stages are commonly found as developmental forms of trypanosomes. There remain, however, a number of forms which are parasitic in the intestinal tract of insects, notably the Chironomidæ and Pulicidæ.

4. The genus Herpetomonas (Leptomonas).—Intestinal parasites of insects, especially muscidæ and hemiptera. In

most cases they are parasites of insects alone, infection being brought about by the ingestion of cyst-infected fæces. Some species are parasitic in the latex of plants, and are taken up by the appropriate plant hemiptera. The distinctive characters (Fig. 222) are the possession of a single flagellum arising from a single kinetonucleus, itself situated in the anterior portion of the body, and the absence of an undulating membrane. Uniflagellate and biflagellate forms occur. Some authorities regard the latter as the result of precocious formation of a new flagellum in anticipation of longitudinal

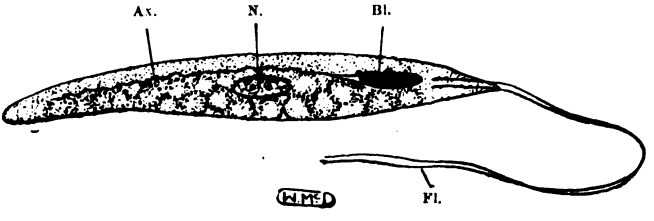


Fig. 222.—Herpetomonas muscæ domesticæ. (*After Prowazek.*)
Fl., Flagella; Bl., blepharoplast; N., nucleus; Ax., axostyle.

division. They have shown that trypanosome forms, but lacking the well-developed undulating membrane so characteristic of the mammalian trypanosome, also occur, the changes in form being in all probability brought about by the migration of the nuclei; all stages being found between the non-flagellate leishmania, through leptomonad, crithidial, to the trypanosome form (Fig. 225).

5. The genus Leishmania includes human parasites, *L. donovani* (Fig. 223), the cause of a general disease, kala-azar, and *L. tropica*, the cause of oriental sore—a purely local

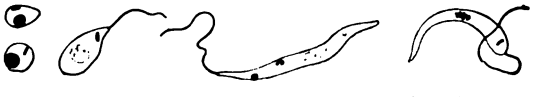


Fig. 223.—Leishmania donovani. (*After Leishman.*)

infection. *L. donovani*, in the Mediterranean area, is found especially in children, and is associated with a similar disease occurring in dogs and caused by the same parasite. The type of parasite found in the vertebrate host is a small oval body multiplying by fission and contained within cells—endothelial cells or macrophages; it is very uniform in size. Each parasite possesses a tropho- and a very distinct kinetonucleus (blepharoplast).

In cultures on the N.N.N. medium the leishmania increase in size, and develop a flagellum, finally assuming an elongated leptomonas form. It is thought that this latter represents a stage of the development of the parasite in the invertebrate host; such a development, however, has not yet been followed. Patton believes that in the case of *L. donovani* the parasite completes its developmental cycle in *Cimex rotundatus*, and in the Mediterranean area there is a certain amount of evidence to incriminate *Ceratophyllus fasciatus*, the dog-flea, as being the definitive host. In the case of *L. tropica*, it has been pointed out that since the sores, as they occur in man, are situated in some uncovered part of the body, the invertebrate host is more likely to be some biting fly or mosquito, or even the sand-fly (Phlebotomus).

Morphologically the leishmania is a leptomonas, but the fact that it occurs in a vertebrate host should justify its inclusion in a separate genus, Leishmania.

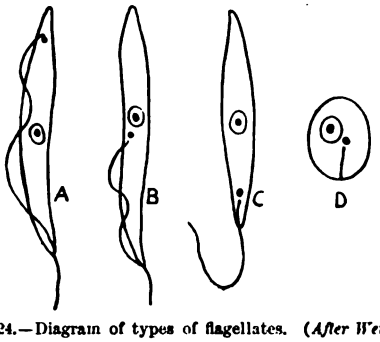


Fig. 224.—Diagram of types of flagellates. (*After Wenyon.*
A, Trypanosome B, Crithidia; C, Leptomonas; D Leishmania.

Nomenclature of the hæmoflagellates.—The generic terms given to these different parasites are also utilized to denote the different stages in their life cycles. Of this cycle the leishmania is taken to represent the most primitive, the trypanosome of vertebrates the most highly developed form (Fig. 224).

One and all these stages occur in the developmental forms of certain trypanosomes in culture, and in the gut of the definitive host the glossina, and even in the vertebrate, as in *T. lewisi*. The generic titles *Trypanosoma*, *Herpetomonas*, *Crithidia*, and *Leptomonas* should, strictly speaking, be reserved for the parasite according to the highest developmental form it is capable of assuming. The accompanying diagram, taken from Wenyon (Fig. 225), illustrates this idea.

Parasites of Uncertain Zoological Position resembling Leishmania

Hæmocystozoon braziliense was found by Franchini in the blood of a man from Brazil. The parasites are sometimes oval, the size of a red blood-cell, containing a large nucleus, a variable amount of pigment, and one

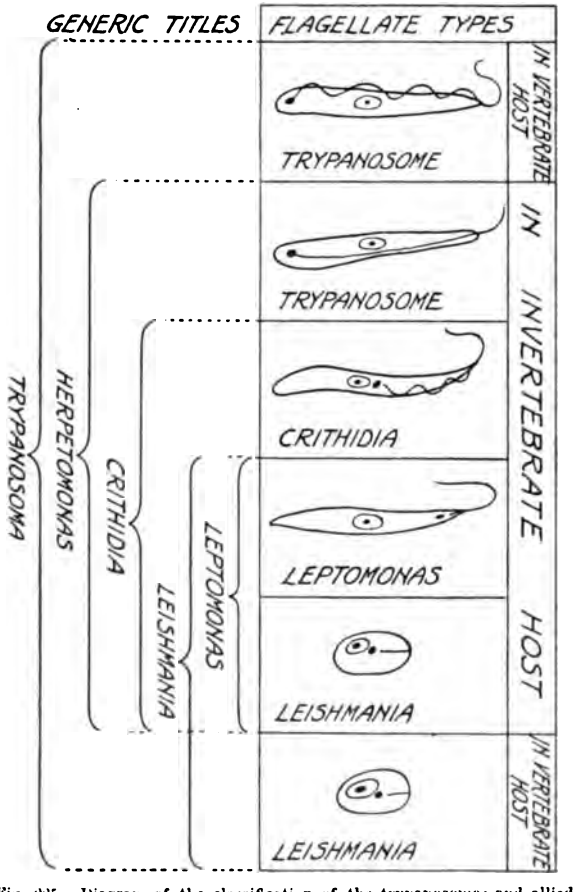


Fig. 225.—Diagram of the classification of the trypanosomes and allied flagellates. (*After Wenyon.*)

or more centrosomes, and sometimes a terminal flagellum arising from a blepharoplast; sometimes non-flagellate and very minute forms were found in the red cells. In a liver puncture, round, clear and encysted

forms occurred, enclosed exceptionally in leucocytes. The patient suffered from irregular fever and anæmia combined with a cystic enlargement in close proximity to the inferior cervical glands. Liver and spleen were also enlarged.

Histoplasma capsulatum was found by Darling in Panama in the tissues of one Chinaman and two negroes who died of some obscure malady characterized by wasting, irregular fever, enlarged spleen, and anæmia. In smears and sections of the lung small bodies were found within the epithelioid cells which bore a great resemblance to leishmania, but differed in possessing no kinetonucleus (blepharoplast). According to Rocha-Lima the parasite is really a yeast-like organism and has nothing to do with the protozoa, but resembles the *Cryptococcus farciminosus* the cause of epizootic lymphangitis of horses in Senegal.

Order iii.—Polymastigina

Polymastigina possess three or more unequal flagella; a distinct mouth opening may be present or absent; in other points they resemble the foregoing. The Polymastigina are

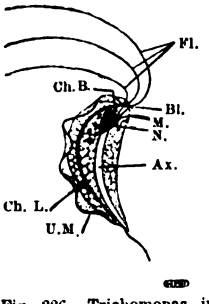


Fig. 226.—Trichomonas intestinalis. (*After Martin and Robertson.*)

Bl., Blepharoplast; Ch. L., chromatinic line; M., mouth; Fl., ant. flagella; N., nucleus; Ch. B., chromatic body; Ax., axostyle; U. M., undulating membrane.

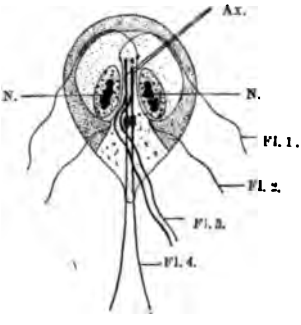


Fig. 227.—Lamblia intestinalis. (*After Wenyon.*)

N., Nuclei; Ax., axostyles; Fl. 1-4, four pairs of flagella.

divided into two divisions or suborders—the Tetramitidæ and the Octomitidæ.

Suborder 1.—The **Tetramitidæ** have three or more flagella arising at the anterior end; the trailing flagellum, if present, may be united to the body by an undulating membrane.

Trichomonas intestinalis (Fig. 226), a common parasite in man, has the trailing flagellum united to the body by such an undulating membrane. It is a matter of controversy whether encystment occurs. Trichomonas, in addition to its motile powers, is capable of a certain amount of amœboid movement it possesses a definite but small mouth cavity, and a stiff supporting rod known as the axostyle.

Tetramitus mesnili also occurs as a harmless parasite in human fæces; it resembles trichomonas in its general features;

but differs in the lack of an undulating membrane and in the presence of a well-marked cystosome in which there is either a flagellum or a membrane; there are three anterior flagella as in trichomonas.

Suborder 2.—The **Octomitidæ,** for the most part intestinal parasites, have six or eight flagella, generally arranged in pairs; the body is bilaterally symmetrical in structure.

Lamblia intestinalis (Fig. 227) is a common parasite in the human intestine; encystment is a common feature; these cysts are ovoid bodies containing two nuclei. On the ventral surface of the free form there is a sucker-like depression. The general structure of the parasite is sufficiently well shown in Fig. 227.

Class III.—SPOROZOA

This class contains four orders of interest:

i. Gregarinidea.
ii. Eimeriinea.
iii. Hæmosporidia.
iv. Neosporidia.

Order i.—Gregarinidea

This order contains the family of Gregarines. The young parasite (trophozoite) is at first a parasite of the endothelial cells, but later, becoming free, lies in the body cavity and in the intestinal canal. The full-grown parasite is of a large size, and has a definite shape and cuticle. Gregarines are found commonly parasitic in the digestive tract of insects; they are not known to occur in the vertebrata. The anterior end of the body may be provided with a rostrum, termed the *epimerite*, armed with hooks and processes; the posterior portion of the body may be divided by a single septum into two segments, known as the *protomerite* and the *deutomerite;* the nucleus, often of a large size and oval shape, is situated in the latter portion. The complete parasite is capable of independent rapid motion.

The Gregarines are divided into two groups, on one of which, Eugregarinæ, a sexual phase—sporogony—only takes place. In the other, Schizogregarines, multiplication is effected by both sporogony and schizogony.

The Eugregarines are further divided into two groups, the cephaline and acephaline gregarines. The cephalines have a well-developed epimerite; in the acephalines the body is not segmented.

In the sporogonic phase two full-grown gregarines approximate to one another, become rounded, and proceed to secrete a tough envelope. Each gregarine breaks up into a number of gametes which conjugate in pairs. The resulting zygotes (sporoblasts) each encyst in a sporocyst in which eight sporozoites are formed; these on entering a new host develop into adult gregarines. The whole cycle takes place within the same insect or earthworm.

become sporonts; the macromerozoites may again repeat the cycle and become once more macromerozoites or micromerozoites.

These sporonts become differentiated into male and female gametocytes and appear in the circulating blood, but only develop further in the invertebrate host. In the intestine of the invertebrate the male and female gametes, having escaped from their cells as motile vermicules, become approximated and fuse to form a zygote (but in the case of *H. stepanowi* of the tortoise four microgametes are first produced by the male gamete). The zygote then apparently becomes an oökinete, encysts, and grows into a large oöcyst containing a variable number of sporocysts, each of which contains six or eight sporozoites, which again in some manner pass into the intermediary host. In the case of the leech the exact manner in which this is performed is not known, but in the case of *H. muris*, which develops in the rat-mite (*Lelaps echidninus*), the mite is devoured by the rat, and the sporozoites, liberated in the rat's intestine, pass through the wall of the gut into the blood-stream, re-enter the liver cells, and become schizonts.

Fig. 231.—H. canis: endocellular in leucocytes and free sporonts. (*After Wenyon.*)

In the leucocytic gregarines, of which the best known is *H. canis* (Fig. 231) described by Christophers and Wenyon, schizogony takes place in the bone marrow and spleen of the dog, and is, as described above, of two distinct types. The macromerozoites in this case pass into the blood, are taken up by the leucocytes, and become gametocytes. Sporogony takes place in the body tissues of the tick *Rhipicephalus sanguineus*. The dog probably becomes infected by eating the tick.

Suborder Adeleidæ.—This suborder is of little interest from the standpoint of human pathology. It consists of intracellular parasites of invertebrates which differ in their life history from the foregoing in that the sporonts do not remain separate as in *Coccidium schubergi*, but associate in pairs, the male sporont becoming attached to the female.

Order iii.—Hæmosporidia

These parasites are parasitic during the greater part of their life cycle; but they exhibit, as do the hæmogregarines, an alternation of generation, sporogony generally taking place in the digestive tract of some invertebrate.

The order comprises the genera *Plasmodium*, *Hæmoproteus*, *Leucocytozoon*, and *Piroplasma*.

1. In the genus Plasmodium the young schizonts occur within red blood-cells, exhibit amœboid movement, and pro-

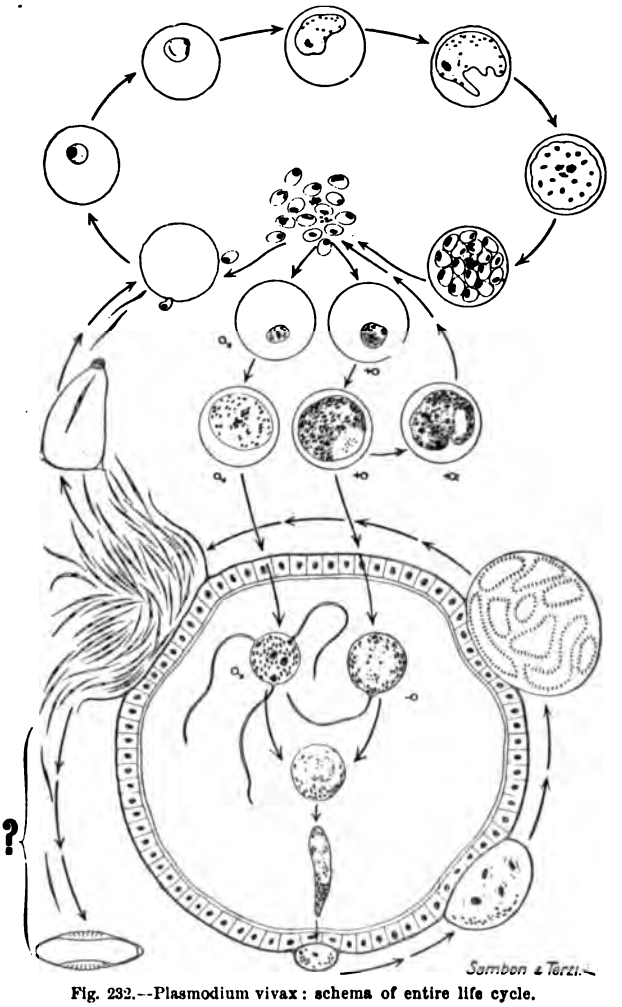


Fig. 232.—Plasmodium vivax: schema of entire life cycle.

duce a pigment called "melanin." The invertebrate host is generally a mosquito. Such are the parasites of human malaria—the benign tertian *Plasmodium vivax* (Fig. 232), the benign quartan *Plasmodium malariæ*, and the pernicious or

subtertian *Plasmodium falciparum* (formerly called *Laverania malariæ*) (Fig. 233). All these human parasites undergo sporogony in mosquitoes of the genus Anopheles. Similar parasites are found in monkeys (Fig. 234), antelopes, bats, and squirrels. In birds an analogous and pernicious parasite is known as Proteosoma (*Proteosoma grassii*, Labbé, 1894), but, in contradistinction to the human malaria parasite, it is transmitted by mosquitoes of the genus Culicinæ, and also by *Stegomyia calopus*.

The life cycle of these parasites (Fig. 232) is extremely well known and has already been described in detail (p. 28).

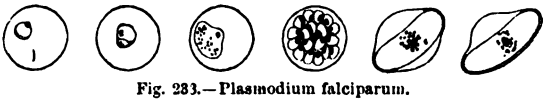


Fig. 233.—Plasmodium falciparum.

The sporozoites, minute slender organisms, are introduced by the proboscis of the mosquito, and enter red blood-corpuscles. The young trophozoite is characterized by its signet-ring appearance, there being a large space in the centre of the body. As the parasite grows this space disappears, and the pigment is deposited in its protoplasm. When full grown, multiplication by schizogony takes place. The nucleus, hitherto single, multiplies by repeated division, each daughter nucleus becoming the centre of a merozoite. A blood corpuscle containing a number of such merozoites represents the characteristic rosette of the malaria parasite. The host cell then

Fig. 234.—Plasmodium kochi. (*After Lühe.*) From a monkey (*Cercopithecus sabacus*).

ruptures, setting free the merozoites; these penetrate other corpuscles and become trophozoites, which may either grow into schizonts or sporonts. These sporonts (gametocytes) are either male or female: the male forms have a large nucleus and a hyaline faintly-staining protoplasm; the female forms have a smaller nucleus and a deeply staining protoplasm. The sporonts are capable of further development only if taken up by the specific kind of mosquito. In the male the nucleus undergoes disintegration, and at the same time the fragments proceed to the periphery of the cell and become nuclei of a number of fine filaments or flagella, and two polar bodies are simultaneously extruded; these flagella are endowed with motile powers, and break free from the cell as microgametes. In the meantime the female sporont, after

giving off a reduction nucleus, is ready for fertilization by the microgamete. The female cell (zygote) is capable of independent movement, and (now termed an oökinete) bores its way through the lining epithelium of the mosquito's stomach, there encysts between the epithelium and the limiting membrane, and becomes an oöcyst. The original nucleus now breaks up into sporoblasts, which in turn break up into sporozoites. The oöcyst then bursts, setting free the sporozoites, which contrive to pass into the salivary glands, whence, with the salivary secretion, they once more enter the blood on which the infected mosquito is feeding. In the avian red blood-corpuscle the young sporont of proteosoma displaces the nucleus of the cell to one side in its growth, and thus may be distinguished from a similar stage in Halteridium.

A form of pigment-producing plasmodium occurs in the blood of reptiles, and is known as Hæmocystidium (Fig. 235). These parasites are of large size, are very numerous in the blood, and do not exflagellate when the blood is drawn. Nothing further is known of their life history.

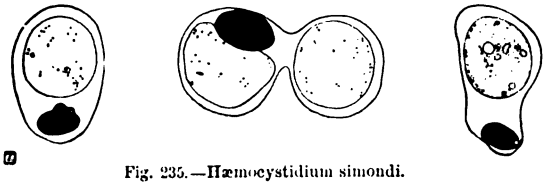


Fig. 235.—Hæmocystidium simondi.

Toxoplasma, a parasite of small size inhabiting the endothelial cells of the peritoneum of mono- and polymorphonuclear leucocytes, was discovered by Splendore in an epizootic amongst rabbits in Brazil. It has since been found in pigeons and in a rodent called the gondi (*Ctenodactylus gondii*) by Nicolle in Tunisia. Multiplication takes place by binary fission; the nucleus is single; no blepharoplast is present. From its morphology it is apparently allied to the hæmamœbæ, but has been relegated provisionally by Nuttall to the piroplasmata.

2. Members of the genus HÆMOPROTEUS (also termed HALTERIDIUM) are parasitic in the blood of many widely different species of birds, and perhaps also of turtles. Within the red blood-corpuscle they grow into a characteristic halter-like shape, partially enveloping but not displacing the nucleus of the corpuscle. In the halteridium of the pigeon the sexual cycle is passed in a hippoboscid fly, *Lynchia maura*, and is similar to that described above, but differs in one respect, namely, that the melanin pigment is extruded by the oökinete, which becomes considerably larger than the sporont found in the blood of the bird, and in this stage is apparently re-inoculated by the lynchia into the pigeon. Possibly the further development of the oökinete takes place within a capillary endothelial cell of the pigeon, but it is afterwards found within a leucocyte in the lung capillaries. In this leucocyte the parasite grows and

breaks up into a number of small forms or merozoites; finally the leucocyte bursts, setting free the merozoites, which, entering red blood-corpuscles, assume once more the typical shape of the sporonts. The male sporont is easily distinguished from the female by the larger size of its nucleus and by the faintly staining properties of its protoplasm.

The life cycle as worked out by Schaudinn was of an entirely different character. It is now known that the blood of *Athene noctua*, the little owl, with which Schaudinn worked, contains a number of blood parasites, namely, a proteosome, a halteridium, two trypanosomes, a leucocytozoon, and a spirochæte. Schaudinn held that the trypanosomes, the leucocytozoon, and the spirochæte formed different stages of the same life cycle.

3. The genus LEUCOCYTOZOON of Daneliewsky must be carefully distinguished from the leucocytic hæmogregarines to which allusion has already been made. The leucocytozoa are elongated oval bodies (Fig. 236), parasitic in the blood of birds. They modify the shape of the host cell, generally a mononuclear leucocyte. Male and female forms are recognized; in the latter the protoplasm takes on a deep stain; no

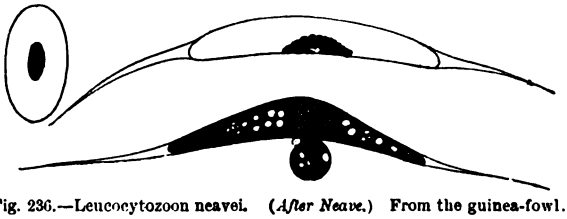


Fig. 236.—Leucocytozoon neavei. (*After Neave.*) From the guinea-fowl.

pigment is formed. Schizogony takes place in the spleen of the bird. Exflagellation and fertilization of the gametocytes occur exactly as in the malaria parasite, but their method of transmission and the definitive host are still unknown.

4. The genus PIROPLASMA consists of a number of minute oval or rod-like organisms, several of which are often contained in the one red blood-corpuscle. No pigment is produced, but the corpuscle is destroyed, the hæmoglobin set free and ultimately excreted by the kidneys of the host.

The best-known piroplasm is *Babesia bovis* (or *bigemina*), the parasite of red-water fever of cattle.

Piroplasma caballi causes biliary fever in horses; *Piroplasma* (*Babesia*) *bovis*, red-water or Texas fever in cattle; *Piroplasma canis* (Fig. 237), malignant jaundice in dogs; while *Piroplasma mutans* is apparently a harmless parasite in the blood of African cattle.

The typical piroplasma is a pear-shaped body dividing by a process of budding, and is found in the red corpuscles of oxen, of sheep, and of a number of wild animals.

The genus Piroplasma has, for convenience sake, been divided into a number of subgenera of doubtful validity.

Theileria is the title reserved for a number of bacillary or coccoid forms. *Theileria parva* (Fig. 238) is the parasite of "East Coast fever" of African cattle.

Another piroplasm, *P. mutans*, is commonly found in the blood of cattle suffering from "East Coast fever," together with the specific parasite *Th. parva*. In the case of the latter the forms in the blood consist entirely of gametocytes; in *P. mutans*, on the other hand, the quadruple forms in the

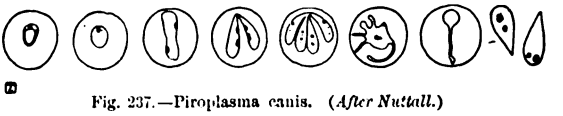


Fig. 237.—Piroplasma canis. (*After Nuttall.*)

erythrocytes apparently represent a stage of the schizogony. Therefore direct inoculation of blood containing *Th. parva* does not produce the disease, whereas infection with *P. mutans* invariably occurs, if schizonts of this species are present in the inoculated blood. The schizogonic stage of *Th. parva* is apparently passed in the internal organs such as the spleen. Splenic puncture in the diseased animals reveals bodies bearing a rough resemblance to a sporulating quartan malaria parasite known as "Koch's bodies"; it is thought that these bodies, which are capable of reproducing the disease on re-inoculation, represent the schizogonic cycle in the splenic cells.

Fig. 238.—Theileria parva. (*After Theiler.*)

Nuttallia is a small oval or pear-shaped piroplasm, also multiplying in the form of a cross. Two kinds are known: one, *N. equi*, causes piroplasmosis in horses in Southern Europe; the other, *N. herpestidis*, is found in the mongoose.

Anaplasma, a small coccoid body, perhaps to be included with the piroplasms and apparently causing great destruction of the red cells, has been described by Theiler in cattle. These bodies are arranged either in the centre of the cell or radially; hence the names *A. centrale* and *A. marginale* have been applied to them. According to some authorities they are not parasites at all, but merely represent a degeneration of the red cell.

Within the red cell the piroplasm consists of little save vacuolated protoplasm and a simple nucleus. The parasites are said to exhibit a certain amount of amœboid movement, and, when free from the cell, to be capable of independent

locomotion. The development in the vertebrate host appears to proceed solely by either binary or quadruple fission.

The transmission of the piroplasms is effected by ticks; in the case of *P. bovis* it is adapted to the life history of the transmitting tick (*Ixodes reduvius* or *Magaropus australis*), and in *P. canis* to *Rhicephalus sanguineus*. The tick is hatched first as a minute six-legged larva, which becomes an eight-legged nymph, differing from the adult only in the absence of genital organs. In each stage the tick feeds but once. The infection is passed to the ova by the infected female tick. The developmental stages of this parasite in the tick are little known; apparently, according to Christophers and Koch, the parasites escape from their red cells and become transformed into star-shaped bodies representing the gametocytes. Conjugation of these bodies takes place, and when complete the zygote becomes a motile body resembling an oökinete. The oökinetes apparently penetrate into the ova of the tick, when they

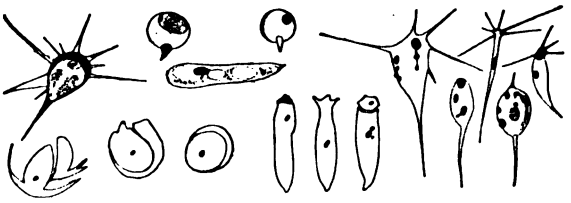


Fig. 239.—Developmental forms of Piroplasma canis in tick's gut. (*After Koch, Klein and Christophers.*)

assume a globular shape. When the egg hatches into a six-legged larva these bodies break up into a number of sporoblasts, which become scattered throughout its tissues. The sporoblasts divide in turn into a number of sporozoites resembling the pear-shaped forms seen in the blood; these, according to Christophers and Gonder, contrive to enter the salivary glands, and thus re-enter the blood-stream when the tick becomes adult and again feeds on blood. (Fig. 239.)

Order iv.—Neosporidia

Parasites belonging to this order are developed from small amœbulæ within the body of the one host. No definitive host is known. The adult parasite is a large cyst contained within a definite membrane and incapable of independent movement. The motile amœbula is followed by a plasmodial intracellular stage in which spore formation is commenced and is continued throughout the life of the parasite. The order is divided into two suborders: (1) the Cnidosporidia, characterized by the possession of polar capsules, and pear-shaped bodies provided with a spiral and delicate filament; (2) the Haptosporidia, in which those features are absent.

The life history of *Sarcocystis tenella*, a Cnidosporidian, will be considered. It is a parasite of vertebrates, sometimes occurring as a cystic white body, known as "Miescher's tubes," visible to the naked eye in the striped muscles of man. As a rule it produces no symptoms. The cyst contains a number of crescentic bodies (spores); in some cases these spores are motile; each spore is provided with a nucleus situated at the blunt posterior end and a striated polar capsule at the anterior end. In this species the mode of propagation from one host to another is unknown, but mice can be infected by feeding on the bodies of others harbouring *S. muris*: apparently in this case the spore germinates in the intestine of its host and sets free an amœbula which eventually reaches the striped muscle. In this situation the nuclei break up to form a plasmodium, and become the central points of many separate cells, called pansporoblasts or sporonts. These sporonts multiply actively and occupy the peripheral zone of the parasite, whereas the central portion is packed with spores in the process of differentiation.

Of the Haptosporidia, one, *Rhinosporidium kinealyi*, is found in man in India. It gives rise to polypoid outgrowths from the septum nasi and from the external auditory meatus. The youngest parasites appear to be round cells provided with a cuticle and a single nucleus. By repeated division of this nucleus the parasite becomes a multinucleate plasmodium. The cyst contents become divided into pansporoblasts in the centre, while the periphery contains the granular nuclei. The sporonts grow in size, and by repeated division form clusters of spores, a kind of a morula enclosed in a membrane. When ripe the cyst bursts and scatters its contents into the surrounding tissues.

Nothing is known of the transmission of this parasite or the manner in which infection is acquired.

Class IV.—INFUSORIA

The Infusoria are represented by *Balantidium coli*, an oval-shaped parasite belonging to the subclass Ciliata. The parasite measures about 60–100 μ in length by 50 μ in breadth. The body is clothed with a thick covering of cilia. There is a lobulated nucleus with a distinct micronucleus lying close to it. The protoplasm contains a variable number of contractile vacuoles; there is a definite anteriorly-situated cytostome or mouth cavity. Nutrition is effected by ingestion of solid particles and by osmosis. The parasite reproduces itself asexually by transverse fission. Conjugation takes place by approximation of two individuals and by the exchange of certain nuclear elements; after this has been effected the conjugants separate. Encystment may take place.

Balantidium coli burrows into the submucosa and causes dysenteric symptoms known as balantidial dysentery (*see* p. 514).

DOUBTFUL GROUPS

Two groups of protozoal organisms of doubtful validity remain to be considered, the Spirochætes and the Chlamydozoa.

1. The Spirochætes

Regarding the systemic position of the Spirochætes a great deal of controversy has been waged during recent years (*see* p. 227). The group comprises a number of types, some of which are parasitic, others free-living forms, such as *Spirochæta plicatilis* and *Cristispira balbiani* of the oyster. Both possess a crest running the entire length of the body; this structure has been wrongly termed an "undulating membrane."

The pathogenic spirochætes are slender thread-like organisms containing chromatic material. Such are *Sp. recurrentis* (*obermeieri*), *S. duttoni* of relapsing fever, *Sp. gallinarum* of fowls, etc.; these species are transmitted by various kinds of ticks (*Ornithodoros*), bugs and lice. In the case of *S. duttoni* the spirochætes apparently break up in the body of the tick into very minute forms, and then pass into the egg, and so to the next generation of nymphs (*see* p. 231).

For the spirochætes of syphilis and yaws the name Treponema was proposed by Schaudinn;* the parasites are termed respectively *T. pallidum* and *T. pertenue.*

2. The Chlamydozoa

A name proposed by v. Prowazek to include a number of doubtful organisms, as the name implies. These problematic bodies are so minute that they are said to pass through a bacterial filter. They are parasites of epiblastic cells, but according to some authorities they merely represent a nuclear degeneration.

It is enough to mention that such diseases as vaccinia, variola, trachoma, epithelioma contagiosa of birds, verruga Peruana, measles, and foot-and-mouth disease of animals, have been ascribed to the agency of these Chlamydozoa.

* Schaudinn believed the spirochætes to be related to the trypanosomes. This conclusion was reached, it is believed, as the result of faulty observations on the blood-parasites of the little owl, which have already been referred to.

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